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Factors Affecting Assessment of Parasitization by *Apanteles fumiferanae* Vier. and *Glypta fumiferanae* (Vier.) on Spruce Budworm Larvae

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Introduction

Sampling to obtain valid estimates of the degree of parasitism in natural populations of insects presents a difficult problem to the quantitative-minded investigator. The method used must adhere to the principles of random sampling, yet it must be truly representative with respect to the occurrence of the parasite in its sampling universe, the host insect, in both time and space.

Methods of estimating parasitization of the spruce budworm, *Choristoneura fumiferana* (Clem.), by *Apanteles fumiferanae* Vier. and *Glypta fumiferanae* (Vier.) have yielded different answers, depending on the manner and timing of collections. For example, Jaynes (1954) and Miller (1958) found that the incidence of *Apanteles* differed according to tree-crown levels, while parasitization by *Glypta* was randomly distributed in budworm larvae at all crown heights. Estimates based on collections at different times in the seasonal development of each have differed also.

Observations in northern Maine during 1950 and 1951 indicated higher parasitization by *Apanteles* and *Glypta* in fourth-instar budworm collections (when the budworm larvae were mining buds) than in second-instar collections immediately after emergence from hibernation. Since both species of parasites attack the budworm in the late summer prior to hibernation of the host, it is impossible for an actual increase in the amount of parasitization to occur in the following spring.

This study was initiated to test the significance of observed differences in parasitism between the hibernating larval collection and the bud-stage collection and to determine, if possible, some of the factors responsible for the observed differences.

Life History and Importance of the Two Parasites

Both *Apanteles* and *Glypta* attack the spruce budworm soon after egg eclosion. There has been some uncertainty whether the parasites attack before or after formation of the hibernaculum by the host. Reports have indicated that the parasites may attack the larvae in both states, although they apparently prefer those in the hibernating condition (Miller, 1958).

The parasite larva overwinters within the host and resumes development when the host becomes active the following spring. The full-grown larva of both species leaves the host and spins a characteristic cocoon among the needles or on the twig. According to MacDonald (1959), *Apanteles* leaves the host somewhat earlier than *Glypta*, generally from the peak of the fourth instar to the pupal period of the budworm. *Glypta*, however, shows less variation in the time of emergence. With the exception that *Apanteles* has never been observed emerging from budworm pupae, similar observations have been made by U.S. Forest Service entomologists in the Adirondacks and northern Maine.

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The adult parasites usually are active from budworm moth emergence through first-instar larval hibernacula formation. Adult *Apanteles* make up the majority of the combined populations of these parasites early in the attack period, while *Glypta* makes up the majority in the latter part of this period. Rarely has the occurrence of two or more developing parasites in a single host been reported. Brown (1946a, 1946b) has outlined in detail the life history of both parasites and has described the external morphology of the adult and immature stages.

The importance and incidence of these two parasites have been discussed by several authors. In eastern United States, *Apanteles* appears to be more important (Dowden et al, 1948) while in Canada *Glypta* appears to be the more important (Wilkes et al, 1948). Dowden et al (op. cit.) indicated the importance of *Apanteles* and *Glypta* in western United States also, where parasitization ran from 12 to 63 per cent, averaging about 37 per cent.

Oviposition Behavior of Parasites in Laboratory

Apanteles and *Glypta* were obtained from field-collected cocoons and maintained in the laboratory for observation of their oviposition behavior with newly hatched budworms prior to hibernacula formation, and with larvae within fully formed hibernacula.

Apanteles Oviposition Behavior

The female *Apanteles* exhibits a characteristic behavior pattern when in the immediate presence of the host. It moves with quick darting motions in an erratic pattern, continuously moving its antennae. The parasite does not move directly to a host, but locates its prey with its antennae during the search pattern.

When it locates the larva, the oviposition act takes place immediately. The oviposition site, as observed, was on the lateral surfaces of the host prothorax. The parasite holds the budworm larva firmly with its mesothoracic legs after having rolled the larva to them with its prothoracic legs. The parasite squats quietly, wings slightly apart and still. The actual thrust is very quick; little or no probing is done with the ovipositor. The host larva is actually impaled. After oviposition, the parasite pushes the host from its ovipositor with its metathoracic legs. There was some evidence of parasites rejecting previously parasitized larvae, but in several cases a female was observed attacking a larva twice. The above remarks refer to the attack of this parasite on newly-hatched budworm larvae before the hibernacula was formed.

In attacking budworm larvae in their hibernacula, *Apanteles* has considerable difficulty with the webbing. Many larvae were rejected and the length of the attack period was considerably lengthened. It appeared as if the host larva must be touched with the antenna to elicit the oviposition response. Ovipositor length, which in *Apanteles* is only a third as long as *Glypta's* (Brown 1946a), may also explain the apparent oviposition difficulty with larvae within the hibernacula.

Glypta Oviposition Behavior

From observations in the Northeast, it seems that *Glypta* is a less active parasite and a much less efficient searcher than *Apanteles*. However, the adult female also exhibits a strongly excited behavior pattern in the presence of budworm larvae. With its antennae moving rapidly, the parasite runs erratically in an apparently undirected manner. When it encounters a budworm larva, it attempts to pin the larva down with its prothoracic legs. Many larvae escape during this process. The oviposition site appears to be the mid-lateral region of the larva. The long ovipositor is bent forward under the abdomen and probing takes

TABLE I

Effect of larval condition on percentage parasitism by *Apanteles* and *Glypta* (simultaneous and divided attack data pooled).

Parasite	Condition of Attacked Host	
	Freely-moving larvae per cent	Immobile larvae per cent
Apanteles	42	16
Glypta	2	50

place. Many hosts successfully held down by the prothoracic legs were released without successful oviposition by the parasite. If the parasite were successful in ovipositing, the host larva was left impaled on the ovipositor and was dragged around until it dropped off. This is in marked contrast to the behavior of *Apanteles*. The above remarks apply to *Glypta* attacking prehibernacula larvae.

In attacking budworm larvae in the hibernacula, *Glypta* is much more successful. The parasite searches out the hibernacula site, and its long ovipositor pierces the webbing easily. It does not seem to have any difficulty with the webbing such as *Apanteles* has.

Effects of Multiple Parasitization

A concurrent study of the effects of multiple parasitization by these two species was conducted to determine: (1) the effect of host condition, i.e., freely-moving first-instar larvae and larvae immobile within the hibernacula, on the success of attack; and (2) whether both parasites survive successfully within the same larva. To obtain this information, *Apanteles* and *Glypta* were allowed to attack freely-moving budworm larvae and larvae within the hibernacula. The tests were set up to permit attack by the two species simultaneously, and attack by one parasite after the other at varying time intervals.

In general, the results were the same whether the parasites were placed together with the host or were separated by time in their attack. Table I indicates the success of the two parasites in their ability to parasitize first-instar spruce budworm.

These data show that *Apanteles* is more successful than *Glypta* in parasitizing the newly-hatched, freely-moving budworm larvae prior to hibernacula formation, whereas the reverse is true when the host is in the immobile, hibernating stage.

An interesting phenomenon was observed relating to the inhibition of one parasite by the other. It is well known that in many cases a larval parasite will inhibit the development of another within the same host. This holds true where several eggs from the same species are laid in the same host and the first larva to hatch inhibits the development of the other eggs, or in the case where one parasite attacks a host first and another parasite attacks the same host somewhat later with the result that the latter fails to develop.

In the case of *Apanteles* and *Glypta*, no field-collected budworm larva has ever shown the presence of two developing parasites either of the same species or of the two different species. Observations made in this study bear this out. In

no case was more than one parasite seen in a dissected larva, but in many cases several *Glypta* eggs were found. Only one of these eggs had hatched to start larva development.

The time interval between attacks appeared to have a bearing on the inhibition effect. This was particularly clear when *Apanteles* attacked the host first, followed by *Glypta*. When one day separated the attacks, eight per cent of the *Glypta* eggs were inhibited. When four days separated the attack, 14 per cent of the *Glypta* eggs were inhibited; and when 11 days separated the attack, 65 per cent of the *Glypta* eggs were inhibited. Inhibited eggs were distinguished from unhatched eggs in that the unhatched eggs showed embryonic development and inhibited eggs showed no embryonation.

Effect of Parasitization on Light Reactions

In conjunction with the foregoing studies, laboratory investigation was made of the light reactions of second-instar budworm larvae immediately after issuing from the hibernacula.

The larvae were tested in a darkened room at room temperatures and humidities. The light arena was constructed of plywood painted dull black. The arena was a right isoceles triangle with a 25-watt frosted bulb placed directly opposite the 90° angle. The bisector distance was 20 inches. The larvae were placed at a specified point in the 90° angle and their subsequent movements were sketched on paper. The time to traverse the distance to the light source was recorded. Each larva was run individually once on the board and then dissected to determine the presence or absence of parasites. The larvae were tested as soon after emergence from the hibernacula as possible, always in less than 12 hours. They were unfed and kept at room temperature.

Nonparasitized Larvae

In this study nonparasitized larvae confirmed the observations of Wellington and Henson (1947) and Wellington (1948) that second-instar spruce budworms are strongly photopositive. The larvae tested were approximately the same age from emergence, and active. The general pattern of travel by the nonparasitized larvae was as follows: the larva started at the apex of the triangle and immediately moved at a 45° angle parallel to the sides of the triangle until an area of maximum light intensity was reached about halfway along either side. At this point the larva reoriented toward the light source and travelled directly to it. Some heat-caused negative reactions were noted when the larva came very close to the light bulb, but this reaction did not detract from the general course. The average time to reach the light source was 20 minutes. Twenty-five unparasitized larvae were tested.

Apanteles-Parasitized Larvae

Four larvae parasitized by *Apanteles* were tested in the arena. Three of these larvae exhibited a strong negative phototaxis or no photic reaction at all. The fourth exhibited a positive photic reaction but was very slow-moving. Its irregular, convoluted track indicated a high degree of disorientation. This larva required 200 minutes to complete the course to the light. Some evidence of the light compass reaction was noted in this larva.

Although only a few known parasitized specimens were tested, their movements — distinctly different from those of nonparasitized larvae — make it clear that parasitism by *Apanteles* strongly modifies the photic reactions and thus the behavior of the host larva.

Glypta-Parasitized Larvae

Four larvae parasitized by *Glypta* were tested in the arena. All four larvae exhibited no photic responses at all. They remained in place for well over 200 minutes each and when prodded with needles showed that they were capable of normal movement. The lack of response is different from that of *Apanteles*-affected hosts and is also different from the reactions of nonparasitized larvae. It is apparent that the presence of *Glypta* in the host larva modifies its behavioral activities.

Field Studies

More detailed field observations on parasitization by *Apanteles* and *Glypta* were made in northern Maine in 1955 and 1956. These observations were aimed at determining the validity of previously observed differences in parasitism in collections of larvae in the hibernating stage (instar II) and the bud stage (instar III-IV). If the differences proved to be significant, it was hoped that the findings of the laboratory parasitization studies would reveal the possible causes of these differences.

Twenty sample trees of balsam fir, *Abies balsamea* (L.) Mill., were selected at random in the Snake River area near Stockholm, Maine. Budworm populations in this area were medium to high and both parasites were present in reasonable numbers.

In view of the previous findings on the vertical distribution of *Apanteles* (Jaynes, 1954), samples were cut from mid-crown height to avoid crown-level differences in parasitization. One entire branch was taken as a sample for each of the collections. This branch was divided into terminal 15-inch twig sections and the excess portion. The position of each sample branch on the tree with respect to cardinal direction was recorded in order to measure the possible effect of exposure on host distribution or density and parasite activity.

The hibernating collection, made during the first week of May, was placed in cardboard emergence boxes and brought to the New Haven Laboratory for larval recovery. All 15-inch twigs from each branch were counted and placed in a labelled box. The excess was placed in another box. Due to the differences in the size of the branches, there were variable numbers of 15-inch twigs in each box. In some cases, two emergence boxes were necessary to hold all the excess from one branch. These boxes were placed on racks and illuminated to draw the larvae into glass vials placed in the side of the box. Water was sprayed into the sealed boxes at intervals to prevent dessication.

In mid-June, when the budworm was in instars III-IV, a branch was cut from each of the same 20 trees at the same height as the hibernating collection. These branches were taken from the same whorl and cardinal direction as the first collection insofar as possible. The sample branches were divided into terminal 15-inch twigs and excess as before and were carefully examined visually for budworms mining in needles and buds or wandering on the foliage. The data of both collections are summarized in Table II.

It was readily apparent that there was a strong shift in budworms on the sampling units in the two collections. Together with the change in population distribution, there was a near doubling of the counts of budworms per 15-inch twig. This indicated that two different host populations were being sampled by the 15-inch twigs in the two collections.

There was also a significant overall change in population numbers, an average gain of 120 budworm larvae on the 15-inch twigs and an average loss of 1,070 budworm larvae from the excess portion of the branch. This gave an apparent

TABLE II

Distribution of budworm larvae on sample branches — northern Maine, 1956 (20 trees).

Collection	Number of larvae on			% Population on		Budworms per 15-inch twig
	twigs	excess	branch	twigs	excess	
Hibernating	431	1314	1745	25	75	2.9
Bud	551	244	795	70	30	4.8
Difference	+120	−1070	−950	—	—	—

net loss of 950 budworms or 54 per cent from the whole branch in the period between the two collections. This undoubtedly reflects the *net* loss in budworms on the individual trees due to intra-stand dispersal in the time period between the two collections. Spring dispersal has been recognized as an important mortality factor in spruce budworm population dynamics and has been ascribed by Miller (1958) to air dispersal to nonhost material, predation, and failure to establish a feeding site.

The larvae from both collections were placed in 70 per cent ethyl alcohol, and random subsamples from each vial were dissected for parasites. The larvae emerging from the cardboard boxes were divided into two groups, Hibernating I and Hibernating II. This division was made when it became apparent that the larvae in the boxes emerged in two groups, one (Hibernating I) almost immediately after placement in the boxes, and the other (Hibernating II) about 7-10 days later. The second emergence coincided with the addition of moisture into the boxes.

Corresponding to the changes or discrepancies in budworm distribution and numbers, there were some apparent changes in the occurrence of *Apanteles* (Table III). There was an average gain of 90 *Apanteles*-parasitized budworms on the 15-inch twigs and an average loss of 174 *Apanteles*-parasitized budworms from the excess between the two collections. This gave a net loss of 84, or 25 per cent *Apanteles*-parasitized larvae from the branch. Thus, although 54 per cent of the hibernating budworm population was lost between emergence from the hibernacula and site establishment in the buds, only 25 per cent of the *Apanteles*-parasitized individuals were lost in this same time period. Sampling error could account for some of the differences between the two collections, but could not conceivably account for this large a difference. These data show that there may be a differential loss due to spring dispersal and its side effects *per se* between parasitized and nonparasitized budworm larvae.

Table III indicates the apparent increase in percentage parasitism by *Apanteles* between the two collections. Percentage parasitism by *Apanteles* on the twigs and excess does not appear to differ in each of the collections.

In view of the decrease in budworm population numbers and the distributional shift on the sample branches, the apparent increase in parasitism from hibernating stage to bud stage (most apparent with *Apanteles*) may be due to one or more of the following: (1) a differential migration of nonparasitized and parasitized larvae to terminal portions of sample branches (from excess to twigs); (2) a difference in the initial amount of parasitism on twigs and excess; or (3) a differential loss of healthy and parasitized larvae during the spring dispersal

TABLE III

Parasitization by *Apanteles* and *Glypta* in collections of budworm larvae in hibernation and bud mining stages (20 trees)

Collection	Number of Apanteles			% Apanteles		% Glypta		Total per cent parasitized	
	Twigs	Excess	Whole branch	Twigs	Excess	Twigs	Excess	Twigs	Excess
Hibernating I	22	—	—	12	14	4	7	16	21
Hibernating II	59	—	—	29	24	6	7	36	31
Total Hibernating[1]	81	250	331	21	19	5	7	26	26
Bud stage	171	76	247	31	31	11	5	42	36
Difference	+90	−174	−84	—	—	—	—	—	—

[1]This is the figure used in previous studies for parasitization by the two species where total number of parasites were divided by total number of budworms.

TABLE IV

Analysis of variance in parasitism by spruce budworm larvae (15 trees). Percentage values transformed to degrees for this analysis.

Source	DF	SS	MS	F
Collection (Hib. vs. Bud)	1	797.97	797.97	9.25*
Trees (whole branches)	14	2,707.50	193.40	2.24*
Units (Twigs vs. Excess)	1	17.70	17.70	.21
Error	43	3,711.68	86.31	—

*Significant at the 1 per cent level

TABLE V

Analysis of variance in parasitism by *Apanteles* in Hibernating I and Hibernating II groups (15 trees). Percentage values transformed to degrees for this analysis.

Source	DF	SS	MS	F
Group (Hib. I vs. Hib. II)	1	1,088.51	1,088.51	12.12*
Trees (whole branches)	14	2,237.21	159.80	1.79
Units (Twigs vs. Excess)	1	25.20	25.20	.29
Error	43	3,861.65	89.79	—

*Significant at the 1 per cent level

period. The validity of these three hypotheses are examined more closely in the discussion.

Statistical Analysis

The data from the field collections were subjected to analyses of variance to determine the significance of the observed differences in budworm parasitism in the two collections. The analyses of *Apanteles* data are given in Tables IV and V. The data for five trees were insufficient for the analysis and thus were eliminated.

Table IV indicates clearly that the observed differences in parasitization by *Apanteles* in the average hibernating and bud collection is real and highly significant. Because of the inter-tree differences in host population density, some significance in the differences between trees is expected. An important fact is the lack of significance between units (twigs and excess). This indicates that no differential parasitization has occurred. Table V also indicates clearly that the observed differences in parasitization by *Apanteles* in the two hibernating collections is very real. The lack of significance for differences in units substantiates that shown in Table IV and gives added weight to the implication that no differential parasitization by *Apanteles* occurs on twigs or excess.

The data on parasitization by *Glypta* were treated in the same manner as the *Apanteles* data. Significance at the one per cent level was shown for the difference in parasitization between the average hibernating collection and the bud collection. No significant difference in parasitism was indicated for the units (twigs and excess), although some increase was noted in the percentage parasitism of host larvae on the twigs.

An analysis of variance was carried out to determine the significance of the effects of population density and exposure on per cent parasitism. No significance was found with respect to exposure, but a near five per cent level of significance was found with respect to population density. A quadrant sum test showed a strong positive correlation between population density and per cent parasitism in the bud stage. A negative correlation was indicated between population density and per cent parasitism in the hibernation stage. However, the data are not adequate on this point.

Discussion

Differences in estimates of parasitism by *Apanteles* and *Glypta* in second- and fourth-instar budworm collections can be quite marked. In this study, the primary cause of these differences appears to be related to the modified behavior of the parasitized larvae. Light reaction studies have shown that parasitized larvae react much differently than nonparasitized larvae. Differences in the oviposition behavior of the two parasites must play only a secondary role.

In discussing the three previously proposed hypotheses for the observed differences in parasitization, consideration must be given to the differences between the two collections and the sampling units.

Data presented in earlier sections have shown that the amount of parasitization by *Apanteles* and *Glypta* is nearly the same on the 15-inch twigs and excess portion of the branch (Table III) at a given collection time. Analysis of the data indicates that there is no significant difference in parasitization by the two species on the 15-inch twigs and the rest of the sample branch in each collection. This eliminates the hypothesis that differential parasitization on twigs and excess was the cause for the observed differences in per cent parasitization. It also can be concluded that the 15-inch twig is an adequate unit for estimates of parasitism and the whole-branch sample is not necessary as stated by Miller (1958). However, the estimate must be considered valid only for a specified time of collection — comparison of parasitism by *Apanteles* and *Glypta* in the second instar and third-fourth instar are not valid.

Tables II and III indicate clearly that there is a much higher average loss of nonparasitized budworms than parasitized budworms in the period between the two collections. In the time interval between the two collections approximately 91 per cent of the lost or redistributed budworm population were nonparasitized. This clearly indicates that there is a differential loss of nonparasitized larvae

(hypothesis 3) and is in direct contrast to the assumption made by Miller (1955) that there is no differential loss due to dispersal and other factors between time of egg hatch and time of sampling. If there were no differential loss, both parasitized and nonparasitized larvae should be redistributed or lost in equal proportions and the observed rise in parasitization estimates would not occur.

In addition to the modified light reactions, the time of emergence from hibernacula is affected by parasitization. The difference between Hibernating collection I and Hibernating collection II brings out this fact clearly. Miller (1958) has observed the same phenomenon of later emergence of parasitized larvae in the Green River project in New Brunswick, Canada. Earlier larvae emerging from hibernation (Hibernating collection I) show a much lower parasitism than the later emerging larvae (Hibernating collection II). Also, the strongly positive photic reactions of nonparasitized larvae, which make up the bulk of the early emergents, indicate that the bulk of the spring-dispersed budworms are nonparasitized. These facts give added support to hypotheses 1 and 3.

One facet of spring dispersal that has not been brought out by Miller (1958) is the loss of larvae in the needle-mining stage (Jaynes and Speers, 1949; Dowden and Carolin, 1950) when a needle drops off with a larva in it. This loss can be substantial and must be distinguished from the lack of feeding sites as is the case when the buds do not open soon enough (e.g., on black spruce). It follows from data presented here that a high proportion of the needle-mining losses will involve nonparasitized larvae since they are the first to emerge and establish themselves in the needles.

Since parasitized budworm larvae are later in emerging from the hibernacula and slower in moving to the terminal portions of the branches, this behavior could act as a survival advantage for the parasite by diminishing the spring dispersal loss of these larvae and also timing this emergence more closely with the opening buds.

Both studies by Miller and those reported here utilized a technique involving the drawing of emerging larvae to light. It seems apparent that a disproportionate number of the later emerging, more heavily parasitized second-instar larvae would never be drawn far from the overwintering sites to light regardless of the type of container which held the sample foliage. This is particularly true if suitable food is available to them in the container. Thus, an unintentional selection of host material has been made in attempts to secure population and parasitization estimates from the spruce budworm stages concerned with *Apanteles* and *Glypta*.

With reference to the three hypotheses, then, the data presented appear to eliminate the possibility that any difference in initial parasitization by *Apanteles* takes place on the twigs and excess, and thus hypothesis 2 is invalid. It is clearly shown that there is both a difference in the migration of parasitized larvae and a differential loss of nonparasitized larvae during the period between emergence from hibernaculum and establishment of bud-mining sites. This indicates that hypotheses 1 and 3 are valid explanations for the observed differences in per cent parasitization between the hibernating and bud mining collections.

In addition, our observations do not bear out the statement by Miller (1959) that *Apanteles* probably attacks budworms in hibernacula more frequently than in the mobile, prehibernacula stage. Oviposition studies of many individuals of both species have shown that the efficiency of *Apanteles* is much better when it is attacking freely-moving larvae. Much higher parasitization is found in these

larvae than in budworms attacked in the hibernacula. On the other hand, the data indicate that *Glypta* is more successful when attacking immobile post-hibernacula larvae. The observations fit in well with field observations on the time of occurrence of the two parasites; *Apanteles* adults are in the field a week to 10 days earlier than *Glypta* adults.

This rather limited study of two parasites and their host indicates very clearly the necessity of a thorough knowledge of the life history and behavior of parasites and hosts before proper sampling methods can be devised and sound conclusions drawn on the parasite-host interactions. Sampling for parasitization in a dynamically changing larval population is at best hazardous (Miller, 1955). All information, however small or seemingly insignificant, tends to lead to refinements of technique which are required for greater accuracy and reliability of estimates.

Summary

1. Oviposition behavior studies of *Apanteles* and *Glypta* have shown that the former is more efficient when attacking mobile spruce budworm larvae and the latter is more efficient when attacking immobile larvae within the hibernacula. The behavior pattern of each species is described.

2. Multiple parasitization studies show that only one parasite of either species can survive in a single budworm host. Inhibition effects on *Glypta* eggs by larval *Apanteles* have been observed. This effect is more pronounced as the time span between oviposition of the two parasites is increased.

3. It has been confirmed that nonparasitized larvae react in a strongly photopositive manner to light, whereas larvae parasitized by *Apanteles* or *Glypta* react negatively, or not at all, to light.

4. Parasitized larvae emerge from the hibernacula later than nonparasitized larvae. This difference in emergence time may be as much as a week to 10 days.

5. It has been found from field and laboratory studies of parasitization of spruce budworm larvae by *Apanteles fumiferanae* and *Glypta fumiferanae* that the difference between per cent parasitism in the hibernating collection and the bud-stage collection is real and significant. This is due primarily to differential loss of nonparasitized larvae in the period of emergence from hibernation to establishment of feeding sites on the buds, which in turn is related to the different patterns of movement of parasitized and nonparasitized individuals on the trees. Nonparasitized larvae move from hibernation to the terminal portions of the branches earlier and in greater proportion than parasitized larvae.

6. It has been found that there is no significant difference in per cent parasitism on a 15-inch twig as compared to the rest of the branch for either collection time.

7. It is concluded that the methods of forcing spruce budworm larvae out of hibernation result in biased data on parasitization.

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The Meyrick Types of Scopariinae (Lepidoptera: Pyralidae) in the British Museum (Natural History), Exclusive of Hawaiian Species

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Introduction

The purposes of this paper are: (1) to validate a considerable number of lectotype selections made in the course of a revisional study of the Scopariinae, and (2) to give, for the convenience of students, a list of Meyrick holotypes and lectotypes in the collection of the British Museum (Natural History), which now contains the types of all but five of the large number of species described by Meyrick in this group. The Hawaiian species have been omitted as volume 8 of Zimmerman's Insects of Hawaii gives full particulars of the type material of Hawaiian Scopariinae, including Zimmerman's lectotype selections.

For each species I give the name under which it was described, the original reference, and particulars of the type specimen. I have not followed Clarke's excellent example of giving photographs of whole specimen and genitalia as I hope to characterize the species in full at a later date. The species are arranged alphabetically by specific name.

List of Species

Scoparia acharis Meyrick, 1885 : 85. Lectotype, ♂, Akaroa, N.Z., 20/I/72, R. W. F[ereday].

Scoparia acompa Meyrick, 1885 : 100. Lectotype, ♂, L. Wakatipu, N.Z., 1200 ft., 15/12/82.

Scoparia acropola Meyrick, 1885 : 101. Lectotype, ♂, Mt. Wellington, Tasmania, 3000 ft., 5/12/82. Meyrick Coll.

Scoparia agana Meyrick, 1912 : 119. Lectotype, ♂, L. Wakatipu, N.Z., .2.11, G. V. H[udson].

Scoparia alopecias Meyrick, 1901 : 570. Lectotype, ♂, Mt. Cook, N.Z., [February]/01, R. W. F[ereday].

[*Scoparia alticola* Meyrick, 1935 : 546. Holotype, ♂, Ruwenzori, 13,900 ft., July, L. Burgeon, in Congo Museum, Tervuren].

Scoparia anaplecta Meyrick, 1885 : 89. Lectotype, ♂, Mt. Wellington, Tasmania, 3200 ft., 5/12/82.

Scoparia animosa Meyrick, 1914 : 103. Holotype, ♀, West Plains, Invercargill, N.Z., 29/12/07, A. P[hilpott].

Scoparia anthracias Meyrick, 1885 : 74. Lectotype, ♂, Launceston, Tasmania, 28/1/82.

Xeroscopa apheles Meyrick, 1885 : 115. Holotype, ♂, Arthur's Pass, N.Z., 4500 ft., 29/1/83. Meyrick Coll., *Scoparia augastis* 5/2.

Scoparia aphrodes Meyrick, 1885 : 75. Lectotype, ♀, Sydney, N.S. Wales, 13/10/79.

Scoparia asaleuta Meyrick, 1907 : 112. Lectotype, ♀, L. Wakatipu, N.Z., .06, G. V. H[udson].

Xeroscopa aspidota Meyrick, 1885 : 115. Lectotype, ♂, L. Wakatipu, N.Z., 1000 ft., 16/12/82.

Xeroscopa asterisca Meyrick, 1885 : 118. Lectotype, ♀, L. Wakatipu, N.Z., 11/1/81, R. W. F[ereday].

Xeroscopa astragalota Meyrick, 1885 : 113. Lectotype, ♀, Mt. Hutt, N.Z., 1/81, R. W. F[ereday].

Scoparia atmogramma Meyrick, 1915 : 202. Lectotype, ♂, Invercargill, N.Z., [September]/13, A. P [hilpott].

Scoparia augastis Meyrick, 1907 : 113. Lectotype, ♂, Invercargill, N.Z., .3.06, A. P[hilpott].

Scoparia autochroa Meyrick, 1907 : 111. Lectotype, ♂, Invercargill, N.Z., .11.05, A. P[hilpott].

Scoparia axena Meyrick, 1885 : 103. Lectotype, ♂, Arthur's Pass, N.Z., 4500 ft., 29/1/83.

Scoparia benigna Meyrick, 1910a : 366. Lectotype, ♂, Mauritius, N. Manders.

Scoparia cataxesta Meyrick, 1885 : 96. Lectotype, ♂, Castle Hill, N.Z., 3000 ft., 17/1/82.

Scoparia chalara Meyrick, 1901 : 570. Lectotype, ♂, Mt. Cook, N.Z., /12/99, G. V. H[udson].

Scoparia chalicodes Meyrick, 1885 : 98. Lectotype, ♂, Christchurch, N.Z., 21/3/82.

Scoparia characta Meyrick, 1885 : 90. Lectotype, ♂, Makatoku, N.Z., 8/3/83.

Scoparia chiasta Meyrick, 1885 : 74. Lectotype, ♂, Sydney, N.S. Wales, 9/5/79.

Scoparia chimeria Meyrick, 1885 : 84. Lectotype, ♂, Masterton, N.Z., 11/13/83.

Scoparia chlamydota Meyrick, 1885 : 82. Lectotype, ♂, Arthur's Pass, N.Z., 3000 ft., 25/1/83.

Scoparia chordactis Meyrick, 1887a : 272. Holotype, ♂, Str. of Magellan, J. J. W[alker].

Scoparia choristis Meyrick, 1907 : 112. [Kaitoke] Wellington, N.Z., 11/84, G. V. H[udson].

Scoparia chrysomicta Meyrick, 1929 : 166. Holotype, ♂, Hiva Oa, Marquesas, 3500 ft., 28.I.25, at light, St. George Exped., C. L. Collenette.

Scoparia chrysopetra Meyrick, 1929 : 169. Holotype, ♂, Society Is., Fautaua, Tahiti, 2500 ft., 13.III.25, at light, St. George Expedn., C. L. Collenette.

Scoparia ciserodes Meyrick, 1920 : 30. Holotype, ♂, Porirua, Wellington, N.Z., .1.18, G. V. H[udson]. *Scoparia chalicodes* 9/7.

Scoparia citrocosma Meyrick, 1929 : 116. Holotype, ♂, Hiva Oa, Marquesas, 3500 ft., 28.I.25, St. George Expedn., C. L. Collenette.

Scoparia clerica Meyrick, 1929 : 166. Holotype, ♂, Hiva Oa, Marquesas, 3500 ft., 28.I.25, St. George Expedn., C. L. Collenette.

Scoparia colpota Meyrick, 1888 : 65. Lectotype, ♂, Wellington, N.Z., 10/1/86.

Scoparia commercialis Meyrick, 1929 : 167. Holotype, ♂, Hiva Oa, Marquesas, 3500 ft., 28.I.25, St. George Expedn., C. L. Collenette.

Scoparia critica Meyrick, 1885 : 88. Lectotype, ♂, Arthur's Pass, N.Z., 3000 ft., 25.I.83.

Scoparia crypsinoa Meyrick, 1885 : 102. Lectotype, ♂, Castle Hill, N.Z., 3000 ft., 19.I.83.

Eclipsiodes crypsixantha Meyrick, 1884 : 343. Lectotype, ♂, Sydney, N.S. Wales, Australia, March 22, 1873.

Xeroscopa cyameuta Meyrick, 1885 : 112. Lectotype, ♂, Mt. Hutt, N.Z., [18]82, R. W. F[ereday].

Scoparia cymatias Meyrick, 1885 : 86. Lectotype, ♂, Arthur's Pass, N.Z., 2500 ft., 9.I.83.

Scoparia cyptastis Meyrick, 1909 : 7. Lectotype, ♂, Invercargill, N.Z., XI.06, A. P[hilpott].

Scoparia deltophora Meyrick, 1885 : 106. Lectotype, ♂, Arthur's Pass, N.Z., 4200 ft., 29.I.83.

Scoparia dinodes Meyrick, 1885 : 85. Lectotype, ♂, Christchurch, N.Z., 13.I.83.

Scoparia dochmia Meyrick, 1905 : 229. Holotype, ♂, L. Wakatipu, N.Z., 1300 ft., [19]04, G. V. H[udson].

Scoparia dryphactis Meyrick, 1911 : 61. Lectotype, ♂, Wellington, N.Z., 21.II.09, A. P[hilpott].

Scoparia elaphra Meyrick, 1885 : 105. Lectotype, ♂, Palmerston, N.Z., 5.III.83.

Scoparia encapna Meyrick, 1885 : 65. Lectotype, ♂, Mt. Arthur, N.Z., 3800 ft., 15.I.86.

Xeroscopa encausta Meyrick, 1885 : 111. Holotype, ♂, Mt. Wellington, Tasmania, 1200 ft., 4.XII.82. *Scoparia favilliferella* 5/4.

Scoparia epicomia Meyrick, 1885 : 99. Lectotype, ♂, Dunedin, N.Z., [18]83, A. P[hilpott].

Xeroscopa epicremna Meyrick, 1885 : 117. Lectotype, ♂, Castle Hill, N.Z., 2500 ft., 18.I.83.

Scoparia epicryma Meyrick, 1885 : 76. Holotype, ♂, Mt. Gambier, S. Australia, XI.

Scoparia eremitis Meyrick, 1885 : 79. Lectotype, ♂, Wirrabarra, S. Australia, 27.X.82.

Scoparia ergatis Meyrick, 1885 : 88. Lectotype, ♀, Castle Hill, N.Z., 3000 ft., 19.I.83.

Scoparia eumeles Meyrick, 1885 : 75. Type material not identified.
Scoparia exterminata Meyrick, 1929 : 169. Holotype, ♀, Rapa Island, Austral Is., 800 ft., at light, 17.IV.25, St. George Expedn., C. L. Collenette.
Scoparia fragosa Meyrick, 1910 : 71. Holotype, ♀, [Denham Bay, Sunday Is.], Kermadec Is., [19]08, G. V. H[udson].
Scoparia gomphota Meyrick, 1885 : 80. Holotype, ♂, Mt. Wellington, Tasmania, 1.II.82.
Scoparia gyrotoma Meyrick, 1909 : 7. Holotype, ♂, L. Tekapo, N.Z., [19]07, G. V. H[udson].
Scoparia halopis Meyrick, 1909a : 72, Pt. 2, Fig. 3. Lectotype, ♂, Auckland Is., N.Z.
Xeroscopa harpalea Meyrick, 1885 : 114. Holotype, ♂, Otira Gorge, N.Z., 1600 ft., I.
Scoparia hemicycla Meyrick, 1885 : 87. Holotype, ♂, Arthur's Pass, N.Z., 3000 ft., 25.I.83.
Scoparia hemiplaca Meyrick, 1889 : 155. Holotype, ♂, Wellington, N.Z., [18]87, G. V. H[udson]. [Reared from moss].
Scoparia homala Meyrick, 1885 : 79. Lectotype, ♂, Adelaide, S. Australia, 21.X.82.
Dasyscopa homogenes Meyrick, 1894 : 464. Holotype, ♂, Sumbawa.
Scoparia idiogama Meyrick, 1935 : 545. Lectotype, Ruwenzori, Camp 4200 m., VIII.1932, Burgeon, in Congo Museum, Tervuren; lectoparatype in British Museum (Natural History).
Xeroscopa legnota Meyrick, 1885 : 117. Lectotype, ♂, L. Wakatipu, N.Z., 1000 ft., 18.XII.82.
Scoparia leptalea Meyrick, 1885 : 98. Lectotype, ♂, Hamilton, N.Z., 17.I.80. B.M. 97.7.
Scoparia leptophaea Meyrick, 1902 : 277. Lectotype, ♀, Chatham Is., [19]00, [R.W.] F[ereday].
Xeroscopa leucogramma Meyrick, 1885 : 119. Lectotype, ♂, Mr. Hutt, N.Z. [18]82, R. W. F[ereday]. The lectotype lacks the abdomen.
Scoparia locularis Meyrick, 1912 : 118. Lectotype, ♂, L. Wakatipu, N.Z., II.11, G. V. H[udson].
Scoparia luminatrix Meyrick, 1909 : 8. Lectotype, ♂, Invercargill, N.Z. X.06, A. P[hilpott].
Scoparia lychnophanes Meyrick, 1927 : 627. Holotype, ♀, Mt. Holdsworth, Tararua Range, N.Z., 4000 ft., Jan., G. V. Hudson.
Scoparia manganeutis Meyrick, 1885 : 102. Lectotype, ♀, Otira Gorge, N.Z., 1600 ft., 26.I.83. The lectotype lacks the head.
Eclipsiodes marmaropa Meyrick, 1890 : 1111. Holotype, ♀, Mt. Kosciusko, N.S. Wales, 5800 ft., Jan.
Scoparia melanaegis Meyrick, 1885 : 92. Lectotype, ♂, Arthur's Pass, N.Z., 2600 ft., 23.I.83.
Scoparia melilurga Meyrick, 1905 : 228. Lectotype, ♀, Wellington, N.Z., 3.I.86.
Scoparia octophora Meyrick, 1885 : 118. Lectotype, ♂, Castle Hill, N.Z., 1000 ft., 15.XII.82.
Scoparia molifera Meyrick, 1926 : 415. Holotype, ♀, [Ashhurst], Manawatu R., N.Z., II.24, G. V. H[udson].
Xeroscopa nephelitis Meyrick, 1887 : 247. Lectotype, ♂, Mt. Kosciusko, N.S. Wales, 6000 ft., 18.I.85.
Xeroscopa niphosphora Meyrick, 1885 : 115. Lectotype, ♂, Castle Hill, N.Z., 2700 ft., 17.I.83, B.M. 97.7.

Xeroscopa nomeutis Meyrick, 1885 : 116. Lectotype, ♂, L. Wakatipu, N.Z., 3500 ft., 17.XII.82.

Scoparia notozeucta Meyrick, 1938 : 83. Lectotype, ♂, Mt. Guntur, Garoet, W. Java, 1350 m., Overbeck.

Xeroscopa octophora Meyrick, 1885 : 118. Lectotype, ♂, Castle Hill, N.Z., 3000 ft., 18.I.83.

Scoparia officialis Meyrick, 1929 : 128. Holotype, ♂, Hiva Oa, Marquesas, 3500 ft., 28.I.25, St. George Expedn., C. L. Collenette.

Scoparia opostactis Meyrick, 1929 : 168. Holotype, ♀, Fatu Hiva, Marquesas, 2000 ft., 31.I.25, St. George Expedn., C. L. Collenette.

Scoparia oreas Meyrick, 1885 : 81. Holotype, ♂, L. Wakatipu, N.Z., 5000 ft., 17.XII.82.

Scoparia organaea Meyrick, 1901 : 569. Lectotype, ♂, Mt. Cook, N.Z., XII.99, G. V. H[udson].

Scoparia orthioplecta Meyrick, 1937 : 138. Holotype, ♀, Vunidawa, Fiji (H. Phillips).

Scoparia oxygona Meyrick, 1897 : 382. Lectotype, ♂, Tasmania, 25.II.91. G.P.

Scoparia pachyerga Meyrick, 1927 : 697. Holotype, ♂, Mt. Holdsworth, Tararua Range, N.Z., 2500 ft., I, G. V. H[udson].

Scoparia paltomacha Meyrick, 1885 : 105. Lectotype, ♂, Castle Hill, N.Z., 2500 ft., 17.I.83.

Scoparia panopla Meyrick, 1885 : 107. Lectotype, ♂, Mt. Hutt, N.Z., I.80, R. W. F[ereday].

Scoparia parachalca Meyrick, 1901 : 569. Holotype, ♂, Mt. Cook, N.Z., 2500 ft., XII.99, G. V. H[udson].

Scoparia parmifera Meyrick, 1909a : 72, Pl. 2, Fig. 2. Holotype, ♂, Auckland, I., N.Z. The type lacks the abdomen.

Scoparia pierga Meyrick, 1885 : 80. Lectotype, ♂, Mt. Wellington, Tasmania, 3400 ft., 5.XII.82.

Scoparia periphanes Meyrick, 1885 : 94. Lectotype, L. Wakatipu, N.Z., [18]80. 5/2. The lectotype lacks the abdomen.

Xeroscopa petrina Meyrick, 1885 : 111. Lectotype, ♂, Mt. Hutt, N.Z., 1.III.76, R. W. F[ereday].

Scoparia phalerias Meyrick, 1905 : 230. Holotype, ♀, Wellington, N.Z., [IV].96, G. V. H[udson].

Scoparia philerga Meyrick, 1885 : 81. Lectotype, ♂, L. Wakatipu, N.Z., 15.XII.82.

Scoparia philetaera Meyrick, 1885 : 93. Holotype, ♂, Bealey R., N.Z., 2100 ft., I.

Scoparia philonephes Meyrick, 1885 : 110. Lectotype, ♀, Mt. Macedon, Victoria, XII.77, G. H. R[aynor].

Scoparia philorphna Meyrick, 1929 : 168. Holotype, ♂, Fautaua, Tahiti, 2500 ft., 13.III.25, at light, St. George Expedn., C. L. Collenette.

Scoparia plagiotis Meyrick, 1887 : 247. Lectotype, ♀, Cambelltown, Tasmania, 29.XII.84.

Scoparia protorthra Meyrick, 1885a : 450. Lectotype, ♂, Sydney, N.S. Wales, 2.XI.84.

Scoparia psammitis Meyrick, 1885 : 99. Lectotype, ♂, Arthur's Pass, N.Z., 4500 ft., 29.I.83.

Scoparia psednopa Meyrick, 1929 : 169. Holotype, ♀. Rapa I., Austral Is., 800 ft., 17.IV.25, at light, St. George Expedn., C. L. Collenette.

Scoparia quaestoria Meyrick, 1929a : 487. Lectotype, ♂, Waitati, N.Z., XI.16. G. V. H[udson].

Scoparia sideraspis Meyrick, 1905 : 231. Lectotype, ♂, Mt. Earnshaw, N.Z., [5300 ft.], [19]03, G. V. H[udson].
Scoparia spectacularis Meyrick, 1929 : 167. Holotype, ♂, Hiva Oa, Marquesas, 3500 ft., 28.I.25, at light, St. George Expedn., C. L. Collenette.
Scoparia spelaea Meyrick, 1885 : 89. Lectotype, ♂, Wirrabara Forest, S. Australia, 29.X.82.
Scoparia steropaea Meyrick, 1885 : 103. Lectotype, ♂, Castle Hill, N.Z., 3000 ft., 19.1.83.
Scoparia synapta Meyrick, 1885 : 78. Holotype, ♀, Mt. Wellington, Tasmania, 3200 ft., 5.XII.82.
Scoparia syndyas Meyrick, 1938 : 84. Holotype, ♀, Java.
Scoparia syntaracta Meyrick, 1885 : 77. Type material not identified.
Scoparia termobola Meyrick, 1938 : 83. Lectotype, ♂, Mt. Guntur, Garoet, W. Java, 1350 m., Overbeck.
Scoparia tetracycla Meyrick, 1885 : 97. Lectotype, ♀, Christchurch, N.Z., 5.III.64, R. W. F[ereday].
Scoparia threnodes Meyrick, 1887 : 246. Lectotype, ♂, Perth, W. Australia, 23.XI.86.
Scoparia thyridias Meyrick, 1905 : 229. Holotype, ♂, [?Wellington], N.Z., [18]94, G. V. H[udson].
Scoparia torodes Meyrick, 1901 : 568. Lectotype, ♂, Mt. Cook, N.Z. [II].01, R. W. F[ereday].
Scoparia trapezophora Meyrick, 1885 : 93. Holotype, ♀, Castle Hill, N.Z., 3000 ft., I.
Scoparia tricitra Meyrick, 1930 : 583. Holotype, ♀, Upper Setakwa R., Snow Mts., Dutch New Guinea, 3000 ft., August (Meek).
Scoparia triclera Meyrick, 1905 : 230. Holotype, ♀, Wellington, N.Z., [19]03, G. V. H[udson].
Scoparia triscelis Meyrick, 1909a : 71, Pt. 2, Fig. 1. Holotype, ♂, [Carnley Harbour or Norman Inlet], Auckland I., [19]09, G. V. H[udson].
Scoparia tyrophanta Meyrick, 1932 : 245. Holotype, ♂, Ruwenzori, Uganda, 1200 ft., 16.VIII.31, G. L. R. Hancock.
Scoparia ustiramis Meyrick, 1931 : 95. Holotype, ♂, Whangarei, N.Z., Patterson.
Scoparia vulpecula Meyrick, 1927 : 697. Holotype, ♀, Bold Peak, L. Wakatipu, N.Z., January, G. V. H[udson].
Scoparia xysmatias Meyrick, 1907 : 111. Holotype, ♂, Old Man Range, Dunedin, N.Z., [19]06, G. V. H[udson].
Scoparia zophachlaena Meyrick, 1923 : 162. Holotype, ♂, Takapuna, Auckland, N.Z., 7.I.13, G. V. H[udson].

Acknowledgments

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Description and Mating Behaviour of *Allothrombium lerouxi*, new species, (Acarina: Trombidiidae), a Predator of Small Arthropods in Quebec Apple Orchards

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The genus *Allothrombium* Berlese, 1903, is an heterogeneous assemblage of about 45 species of mites, of which 13 species have been described from both the Palaearctic and Ethiopian realms, nine from the Australian and three from the Oriental. Five species are Neotropical, while to date only two species have been reported from the Nearctic. *A. brevitarsum* (Berlese), 1888, *A. sericoideum* Berlese, 1910, *A. crassicomum* Berlese, 1910, and *A. succinctum* Berlese, 1917, are listed by Thor and Willmann (1941) from South America; *A. metae* Boshell and Kerr, 1942 was described from Colombia and subsequently recorded from Panama (Michener, 1946). Ewing (1909, 1917) described two species from the United States: *A. missouriense* (Ewing), 1909, from Missouri and *A. pulvinum* Ewing, 1917, from Illinois. The characters of the mite described below are distinct from those of the Palaearctic species. Its affinities appear to be to the Neotropical and Nearctic forms but it differs from them in the following particulars: from *A. sericoideum, A. crassicomum, A. succinctum* and *A. metae* in having shorter body setae clothed with longer pectinations; from *A. brevitarsum* in having a wider crista metopica and more slender pedipalps; from *A. missouriense* in having a body over three times greater in length and width. *A. pulvinum* is similar to the species herein described in some respects but as the original description does not mention characters such as crista metopica or tarsus length it is imposible to be certain of this. Furthermore, no quantitative measurements are given save overall length (3.30 mm.) and width (2.50 mm.). These measurements fall within the ranges observed for the species described below but should not be used as absolute criteria because of pronounced intraspecific variability produced by the integumental flexibility. Howard (1918) figures the pedipalps, chelicerae and body setae of *A. pulvinum*; the former appendages appear much more slender and elongate, while the body setae possess shorter pectinations. Considering as well the facts of geographic distribution and habitat, I am inclined to consider the two as distinct species.

The mite described below was collected from dead leaves and the grass under apple trees in an orchard near Rougemont, Quebec. A description of this orchard is given by LeRoux and Reimer (1959). The species is named in honour of Dr. E. J. LeRoux, in appreciation of contributions made by him to the study of entomology at Carleton University. I would like to thank Drs. H. H. J. Nesbitt, E. L. Bousfield and W. R. Richards who determined the spider, woodlice and collembolans mentioned below, and Drs. H. H. J. Nesbitt and L. Davies who read the manuscript and made valuable suggestions and corrections.

Description

Unless otherwise indicated, the averages given refer to measurements made on fifteen individuals, both preserved in alcohol and mounted on slides. Range of dimensions is given first, followed by the average in brackets. Habit sketches were made freehand, others with the aid of an Eddinger projection apparatus.

Female (Figs. 1, 2). Idiosoma (body exclusive of gnathosoma) length 2740μ-3655μ (3105μ), greatest width just posterad of the first and second coxae, 1525μ-2255μ (1835μ), and narrowest immediately posterad of the third and fourth coxae, 1400μ-1950μ (1570μ). Ratio of average greatest width of idiosoma to average

length 1:1.69; ratio of average width at narrowest part of idiosoma to average width at widest part 1:1.17. Idiosoma of unengorged female with prominent shoulders as in male; engorged gravid female sub-oval in outline when viewed from above. Idiosoma covered with uniform, heavily pectinated setae, 65-70μ in length (Fig. 5).

Genital orifice (Fig. 13) slightly posterad of the third and fourth coxae; length 315μ-405μ (355μ). Genital and paragenital valves (internal and external rings of Feider, 1955) each covered with a single row of plumose setae and overlying three pairs of genital acetabula. Genital valve bearing approximately 33 setae with much shorter pectinations than are found on the body setae; paragenital valve bearing 15 setae similar in appearance to body setae. Uropore located approximately halfway between genital orifice and posterior tip of idiosoma. Distance between genital orifice and uropore 380μ-715μ (515μ), extremely variable because of wrinkles in integument. Length of uropore 95μ-125μ (110μ). Each uropore valve with four short, stout setae with a few barbs.

Idiosoma dorsally with a series of puncta marking the loci of muscle attachments; in gravid females the puncta sometimes rendered almost invisible by the tightly-stretched integument.

Gnathosoma dorsally with a distinctive crista metopica (Fig. 9), of average length 510μ and subdivided into three areas: median antesensillar plate expanded apically from a narrow, basally sculptured stalk; median sensory area amphora-shaped with two angular anterolateral, unsclerotized areas and a larger oval median one; posterior sclerite sub-pyriform and more or less articulated with the sensory area. The roughly paddle-shaped median antesensillar plate with numerous long (200μ) forward-directed plumose setae. Sensory area with one pair of sensilla or pseudostigmatic organs directed forward at an angle of about 60 degrees, approximately 270μ in length and clothed with minute barbs on distal half. Distance between bases of sensilla 100μ-170μ, average of 10 individuals 120μ. Sensory area supported on either side by a parasensillar plate bearing numerous posteriorly-directed plumose setae; edges of shield sometimes poorly delineated from surrounding integument. Adjacent and anterior to each parasensillar plate and lateral to the median antesensillar plate a curved supra-ocular plate, convex medially, concave laterally, and bearing numerous long, anteriorly directed, plumose setae. The supra-ocular plates not connected by an anterior sclerite such as found in *A. pumilio* André, 1936. Eyes pedicellate, situated laterad of the supra-ocular plate. A pair of ocelli, with the larger of the pair anterior, on each eye-stalk; length of stalk, including ocelli, 115μ-155μ(130μ).

Chelicerae anterad of the crista metopica (Fig. 6), 570μ in length, including the digitus mobilis with a length of 115μ-140μ (125μ). Digitus mobilis with seven to nine teeth dorsally. Chelicerae bearing posteriorly, in Feider's (1955) "respiratory area", a pair of stigmata connected with the emergent peritremes. Length of peritreme and the number of over-lapping scales making up this structure have been noted by previous writers (Oudemans, 1916; Feider, 1955), but these characters are extremely variable. Ventrally, gnathosoma with maximum width 335μ-430μ (350μ). Pedipalp (Fig. 10) strongly developed, width of femur 190μ-220μ (200μ). Apical seta (tibial claw) of pedipalp 70μ-95μ (80μ); pedipalp tarsus claviform, 215μ-285μ (250μ) in length, 65μ-80μ (75μ) in width and bearing a greater number of setae laterally than medially (Figs. 11, 12).

Legs in order of decreasing length: I: IV: II: III. Each ramus of tarsus I pulvillus bearing approximately 20 branches; these in turn bifurcating distally.

Male (Figs. 3, 4). Idiosoma length 2190μ-3230μ (2680μ). Shoulders of idiosoma

TABLE I

Dimensions of Female Terminal Podomeres (microns)

Podomere	Minimum	Maximum	Average
Tarsus I width	170	238	200
Tarsus I length	475	620	540
Tibia I length	450	580	460
Tarsus II length	380	475	445
Tarsus III length	335	470	400
Tarsus IV length	430	525	470

more prominent than in female, 1645μ-2190μ (1930μ) in width. Narrowest part of idiosoma posterad of the third and fourth coxae, 1220μ-1765μ (1460μ). Ratio of average greatest width to average length of idiosoma 1:1.38; ratio of average width at narrowest part to average width at widest part 1:1.32. Idiosoma as in female covered with numerous, uniform, heavily plumose setae 65μ-70μ in length.

Genital orifice posterad of the third and fourth coxae slightly larger than in female, 335μ-440μ (370μ). Genital and paragenital valves present, bearing plumose setae and overlying three pairs of genital acetabula. Internal supporting structures as described for *A. fuliginosum* (Hermann), 1804 by Feider (1959), not observed in this species. Uropore position variable, as in female, uropore length 80μ-115μ (105μ). Valves of uropore covered with short, plumose setae.

Dorsally the muscle puncta prominent (Fig. 4), often more so than in the female.

Crista metopica slightly larger than, but basically similar to, that of female: average length 535μ; distance between bases of sensilla 105μ-170μ (130μ). Eye stalk, including ocelli, 120μ-160μ (145μ) in length.

Chelicerae 560μ in length including digitus mobilis, the latter with a length of 115μ-145μ (130μ). Digitus teeth, stigmata and peritreme as in female. Ventrally the maximum width of gnathosoma 380μ-475μ (420μ). Width of pedipalp femur 190μ-240μ (215μ). Apical seta (tibial claw) of pedipalp 70μ-105μ (90μ) in length; palp tarsus claviform, 215μ-260μ (240μ) in length, 70μ-90μ (80μ) in width and bearing a greater number of setae laterally than medially.

Legs in same order of decreasing length as in female. Each ramus of pulvillus on tarsus I bears approximately 22 distally-branching teeth. Tarsus I noticeably longer in male than in female (Figs. 7, 8).

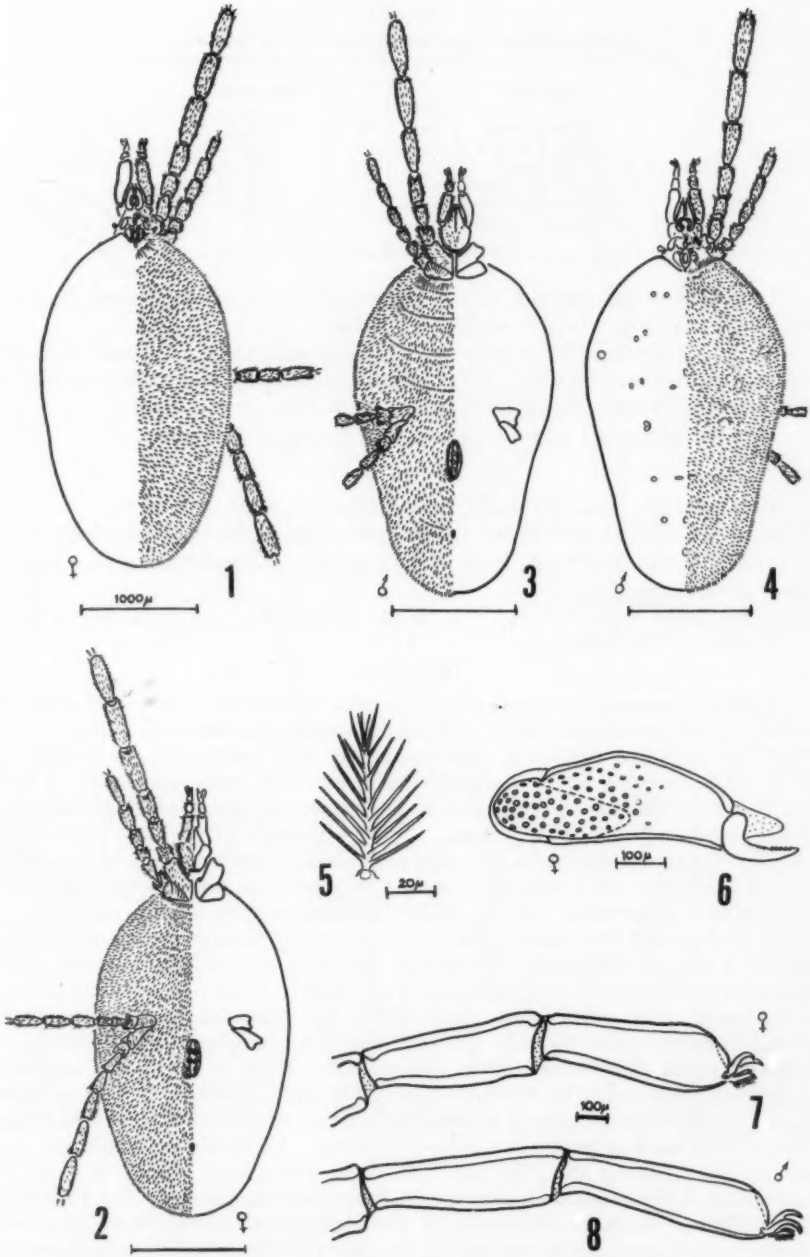
Dimensions of Holotype

Female. Length of idiosoma 3315μ, greatest width 2255μ, least width 1935μ. Length of body setae 65μ-70μ. Length of genital orifice 355μ, of uropore 125μ. Length of posterior setae of genital valve 80μ, of uropore setae 70μ.

TABLE II

Dimensions of Male Terminal Podomeres (microns)

Podomere	Minimum	Maximum	Average
Tarsus I width	190	240	210
Tarsus I length	450	690	585
Tibia I length	460	645	520
Tarsus II length	360	500	450
Tarsus III length	335	450	400
Tarsus IV length	430	570	505



Figs. 1-8. *Allothrombium lerouxi*, new species. 1. Gravid female, dorsal. 2. Same, ventral. 3. Male, ventral. 4. Same, dorsal. 5. Body seta. 6. Chelicera, lateral. 7-8. Terminal podomeres, leg I.

Note: Scale indicated by heavy line beneath drawings.

TABLE III

Dimensions of Holotype Terminal Podomeres (microns)

Podomere	Dimension
Tarsus I width	190
Tarsus I length	610
Tibia I length	580
Tarsus II length	410
Tarsus III length	395
Tarsus IV length	485

Length of crista metopica 615μ. Length of sensilla 270μ; distance between sensillary bases 115μ. Length of eye stalk 135μ.

Length of chelicera 625μ including digitus mobilis, the latter 120μ. Greatest width of gnathosoma (ventral) 425μ. Width of pedipalp femur 190μ, length of tibial claw 85μ, length of palp tarsus 245μ, width 70μ.

Pulvillus of tarsus I with two rami, each bearing 17 branches.

Type Data

Type Habitat: On grass and dead leaves under apple trees.

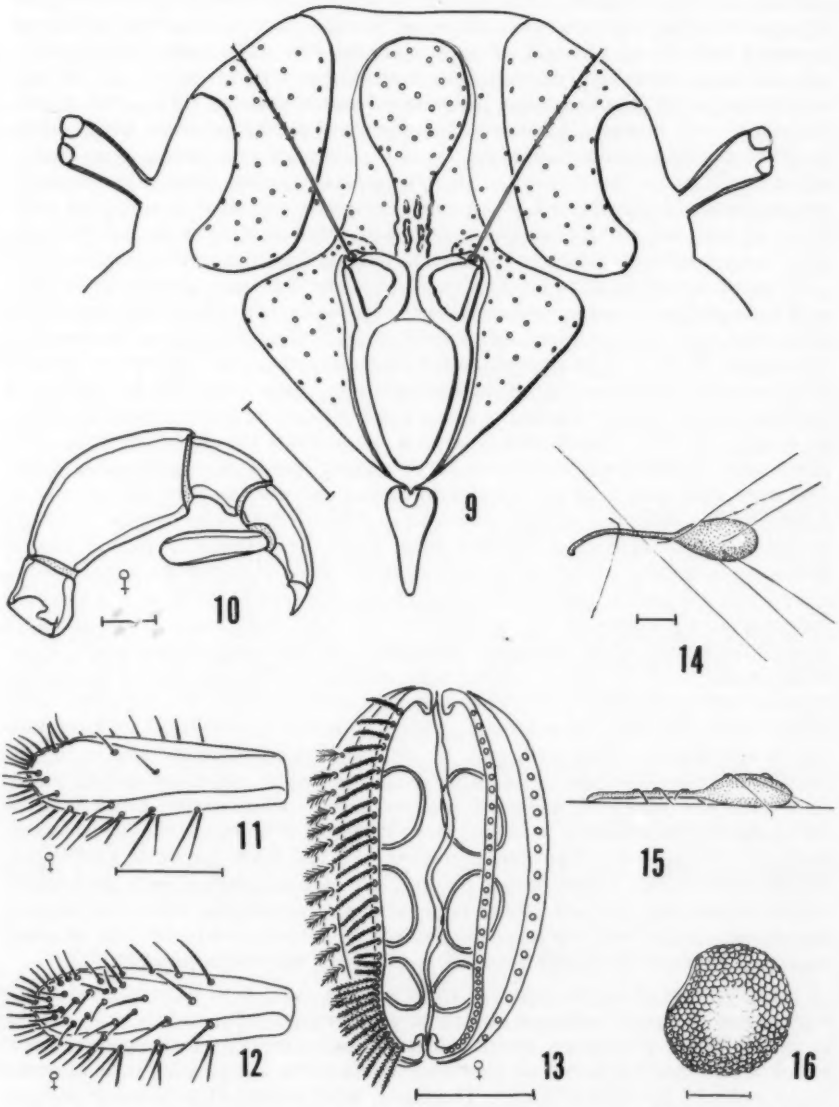
Holotype: ♀, Cistercian Fathers' apple orchard, Rougemont, Quebec, April 21, 1960 (W. W. Moss); No. 7364 in the Canadian National Collection, Ottawa.

Allotype: ♂, same data.

Paratypes: Same data. 2♀♀, 2♂♂ in the C.N.C.; 1♀, 2♂♂ in the Carleton University Collection.

Behaviour

LeRoux (personal communication) has observed that the adults of this species become active around the middle of April, depending on weather conditions. The adults are voracious predators, running rapidly over and under the surface of leaves while carrying out a thorough search for small arthropod prey. I have seen the mites feeding on ants, various caterpillars and spent males of the wolf spider *Trochosa pratensis* (Emerton). On one occasion a large male *T. pratensis* was observed pinned down by six mites, each holding firmly to a leg of the spider with its pedipalps and repeatedly inserting its chelicerae through the membrane between two podomeres. As the spider became quiescent, due to the effect of either the injection of a toxin or the removal of body fluids, one mite inserted its chelicerae into the abdomen. Eventually the spider was reduced to a dry shell. Howard (1918) states that *A. pulvinum* feeds actively in the field on small coleopterous larvae, adult chironomids, small spiders and plant lice, but that the adults seemed to prefer aphids taken by climbing shrubs to a height of two or three feet. LeRoux (personal communication) observed the adults of *A. lerouxi* climbing apple trees, presumably in search of aphids. In the laboratory, pint culture jars lined with the plaster-charcoal-vermiculite mixture used by Wharton and Fuller (1952) were used to maintain a colony of mites. Condensation inside jars was avoided by replacing the glass lids with paper towelling. Adults in captivity took freshly-killed woodlice of the species *Porcellio spinicornis* Say and *Trachaeoniscus rathkei* (Brandt). Colonies of the collembolan *Pseudosinella petersoni* Börner were maintained in the culture jars but the adults were not observed to feed on them. Engorged adult mites are markedly larger than their unengorged counterparts. Cannibalism is of frequent occurrence in the field, as well as under laboratory conditions; the larger females are frequently observed feeding on the smaller males.



Figs. 9-16. *Allothrombium lerouxi*, new species. 9. Crista metopica. 10. Pedipalp, lateral. 11. Pedipalp tarsus, medial. 12. Same, lateral. 13. Genital orifice. 14. Spermatophore, from above. 15. Same, from side. 16. Egg.

Note: all setae removed from crista, Fig. 9. The heavy line beneath each drawing represents 100μ.

Epigamic activities were observed in adults in captivity. Adults do not copulate but effect fertilization by means of spermatophores (Figs. 14, 15). A male in a laboratory culture chose an area about four centimeters square on a piece of paper towelling placed in the culture jar; in some cases the area was horizontal, in others inclined to an angle of approximately 45°. The male moved slowly over the area, drumming on the paper continually with his front pair of legs, which were raised at a sharp angle and lowered simultaneously. These movements contrasted with normal exploratory behaviour, when the substrate is tapped by the front pair of legs alternately, similar to the alternate movements of an insect's antennae. After a few minutes of this methodical tapping, other males began to appear, presumably attracted by the movements or sound of the original male. These in turn began tapping movements and often strayed onto the defended area; an encroaching male was immediately engaged by the territory defender in a strenuous wrestling match. The two males met head-on, grasped each other with their pedipalps and tapped each other vigorously with their front legs, while at the same time each endeavoured to maintain its footing and wound its adversary with its chelicerae. The struggle lasted from several seconds to over a minute. The loser ran, walked or wandered aimlessly away, depending on the severity of the contest; the victor followed as far as the boundary of the territory but made no move to follow once the defeated mite was outside the defended area. The victor then returned and continued his drumming, ready to engage other males. The same male may take part in several battles and may or may not succeed in defending his territory against all comers. Occasionally the original territory holder may wander a short distance away from the defended area, but returns almost immediately. Eventually the dominant male elevated his abdomen for several seconds and a whitish glistening object was visible within the expanding and contracting valves of the genital orifice. The male lowered his abdomen close to the surface of the substrate, depositing a stalked spermatophore which was subsequently covered and tied down with several silk-like threads. The spermatophores are a glistening white when first deposited but soon take on a dull white colour and in time become yellowish. They consist of a cylindrical stalk supporting an apical bulb. The stalk may be slightly expanded basally and is 300μ in length; the bulb is globular or ovoidal and 200μ in length. Spermatophores placed on a slide and observed under oil immersion by means of the phase contrast microscope were observed to release large numbers of spherical, highly refractile bodies 5μ in diameter. The spheres moved back and forth erratically; no flagella or cilia were visible. After several minutes two elongate dark objects were visible within several spheres and at the same time similar objects were seen moving rapidly across the field. It was not possible to determine whether the spherical objects produced the smaller elongate mobile ones but this is possible.

The process of spermatophore deposition may take up to two minutes, during which time the male continues his drumming intermittently; usually only one leg is used. While depositing spermatophores, males are extremely vulnerable to attack from other mites, but on only one occasion was a depositing male observed to be molested by another mite. The latter, who wandered in from an adjacent area, attacked from the rear, drove the defenceless male a few centimeters away, then ceased its aggression, while the other once again began to deposit a spermatophore. Often the movements of the dominant male acted as a stimulus to surrounding males, up to five of which were seen to initiate spermatophore deposition around the periphery of the territory immediately following elevation of the dominant male's abdomen. Each male may deposit several spermatophores. Eventually the area becomes dotted with spermatophores and is deserted.

On one occasion only a female was seen to enter a territory. The defending male approached her and the two spent the next few seconds tapping each other on the dorsum with their front legs. They circled each other several times, then the female walked away. I was not successful in observing whether the female picked up a spermatophore; the male continued his drumming after her departure. It is possible that the drumming of the territorial male serves a twofold function, first to attract other males and assure an adequate concentration of spermatophores, and secondly to attract females for the purpose of fertilization.

Gravid females in the field burrow under leaves to deposit their eggs. Under laboratory conditions the mites crawled downward through the vermiculite and into hollows in the patching plaster-charcoal base located between the plaster and glass. The hollows had been constructed beforehand following the method outlined by Borland (1956). The eggs (Fig. 16) are spherical, 200μ in diameter, with a small concavity on one side. Reddish orange in colour, they are laid in compact masses of approximately 300 eggs. One female was observed lying on her back in the process of oviposition. The eggs as they issued from the genital orifice were passed slowly forward in a loose string, each egg fitting into the concavity of the egg preceding it. The legs of the mite, held over the body in the form of an arch, served to guide the eggs toward the gnathosoma. In this region the eggs were manipulated by the pedipalps to form a compact ball. It is possible that a strengthening layer of silk was added.

In the field (LeRoux, personal communication) the larvae appear in late May and early June. The host of the larva is at present unknown; *A. fuliginosum* larvae have been recorded from aphids (Feider, 1955), while the larvae of *A. metae* were found by Michener (1946) attached to Lycosid spiders of the genus *Pirata*. An attempt will be made to determine the host of *A. lerouxi*. Nymphs with food habits similar to the adult appear in late summer and subsequently transform to adults which are active in the orchards until the onset of cold weather. The adults overwinter in the soil and emerge in the spring.

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Infection of the Jack Pine Budworm, *Choristoneura pinus* Freeman, with a Nuclear Polyhedrosis Virus of the Spruce Budworm, *Choristoneura fumiferana* (Clemens), (Lepidoptera: Tortricidae)[1]

By G. R. Stairs

Introduction

A nuclear polyhedrosis virus has been isolated from the spruce budworm, *Choristoneura fumiferana* (Clemens) (Bergold, 1949; Bird, 1949; Bergold, 1951; Bird and Whalen, 1954; Bird, 1959), but no similar virus has been recovered from the jack pine budworm, *Choristoneura pinus* Freeman. Since these two species are very closely related (Smith, 1953) it was of interest to determine if *C. pinus* is susceptible to the *C. fumiferana* virus.

Methods

Late fifth and early sixth stage larvae of *C. pinus* were collected from jack pine in southern Manitoba in July, 1958, and shipped by air express to Sault Ste. Marie, Ontario. The larvae were placed individually in small petri dishes and fed fresh balsam fir foliage. Using a small wire loop, heavy oral doses of a *C. fumiferana* virus suspension containing about 10×10^7 polyhedra per ml. of water were fed to 112 *C. pinus* larvae while 74 were untreated. The insects were examined daily and smears from dead individuals were examined under the phase-contrast microscope for polyhedra.

This experiment was repeated in July, 1959, with a shipment of *C. pinus* larvae from northwestern Ontario. The second experiment differed from the first in that the larvae were more mature and the insects were infected by allowing them to feed on balsam fir foliage dipped in a *C. fumiferana* virus suspension containing 10×10^6 polyhedra per ml. of water. Forty-one larvae were fed the treated foliage and 42 were fed foliage dipped in sterile distilled water.

Results

When *C. fumiferana* larvae were fed *C. fumfierana* virus 62.5 per cent of them died from polyhedrosis (Table I). Similar results were obtained when *C. pinus* larvae were fed the same virus. In two tests 41.9 and 46.4 per cent of the *C. pinus* larvae and pupae died from polyhedrosis. These results show that both species are probably equally susceptible to the *C. fumiferana* virus.

When early sixth instar *C. fumiferana* larvae were fed virus propagated in *C. pinus*, the proportion infected and the rate of mortality resembled those obtained when similar larvae were fed the virus propagated in *C. fumiferana* (Table I). This indicates that there was no apparent change in the virus following one passage through the closely related host.

Summary

Choristoneura pinus Freeman is susceptible to the nuclear polyhedrosis virus isolated from a closely related species, *Choristoneura fumiferana* (Clemens).

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[1]Contribution No. 16, Insect Pathology Research Institute, Canada Department of Agriculture, Sault Ste. Marie, Ontario.

TABLE I

Infection of (1) *C. fumiferana* with *C. fumiferana* Virus,
(2) *C. pinus* with *C. fumiferana* Virus, and (3) *C. fumiferana* with Virus Propagated in *C. pinus*.

Controls		**C.f. Larvae Fed C.f. Virus		C.p. Larvae Fed C.f. Virus		C.f. Larvae Fed C.f. Virus Propagated in C.p.		No. of Days to Death	Percentage Mortality from Polyhedrosis		
Species and No.	Percentage Diseased	No.	Instar	No.	Instar	No.	Instar	X ± S.D.	Larvae	Pupae	Total
C.f. 24	0	24	Early VI					14.1 ± 3.3	58.3	4.2	62.5
C.p. 74	0			112	Early VI			10.4 ± 3.3	41.0	0.9	41.9
C.p. 42	0			41	Late VI			21.2 ± 5.7	14.6	31.8	46.4
						24	Early VI	15.4 ± 5.7	50.0	4.2	54.2
						*24	Early VI	12.5 ± 2.6	41.7	0	41.7

*Virus was extracted from pupae.
**C.f.—*Choristoneura fumiferana* (Clemens).
C.p.—*Choristoneura pinus* Freeman.

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(Received April 15, 1960)

The Growth Characteristics, in Terms of Live Weight, of Some Grasshoppers (Orthoptera: Acrididae) of Western Canada[1]

By L. G. Putnam and E. G. Peters[2]

Although the live weights of the successive stages of some of the old world Acrididae are known (Bodenheimer, 1929; Key, 1936; Duarte, 1938; Husain, *et al.*, 1946; Davey, 1954; Richards and Waloff, 1954), this information has been obtained only for *Melanoplus bilituratus* (Wlk.) among the grasshopper species of Western Canada (Smith, 1958). In addition to the establishment of growth curves, weight data are useful for computing the biomass of acridid fauna in any situation. As data accumulate to permit the development of a generalized relationship of food consumed to body weight, (e.g. Davey, 1954; Misra, 1956; Gangwere, 1958; Smith, 1958; Putnam, unpublished data), live weight could become a useful quantity for estimating the damage potential of any acridid population.

This paper presents weight data on Western Canadian species representative of what may be arbitrarily classified as small (*Melanoplus dawsoni* (Scudd.)), medium (*M. bilituratus* (Wlk.), *Camnula pellucida* (Scudd.), and *M. packardii* Scudd.), and large, (*M. bivittatus* (Say)). All have been recognized as economic in some degree except *M. dawsoni;* all are Cyrtacanthacrinae except the oedipodine *C. pellucida.*

The grasshoppers used in this study were hatched in the laboratory and reared to the adult stage in the laboratory at Saskatoon, in cages of a design adapted from that described by Hunter-Jones (1956). Incandescent lamps, burned for about nine hours daily, produced temperatures in the cages of about 95°F.; at other times, temperatures fell to the surrounding room temperatures. All species were fed on the outer leaves of head lettuce imported from California or Arizona. Irrespective of the apparent food plant adaptations of the various species, this food produced grasshoppers that appeared of normal characteristics in comparison with those found under natural conditions. Rearing was done intermittently from October, 1954, to December, 1958.

Grasshoppers were weighed within 24 hours after hatching, after entry into each of the four succeeding nymphal instars, and after entering the adult stage. Newly moulted nymphs were removed from the rearing cages daily, and all those of any one stage weighed in bulk. They were then transferred to other cages so that further newly moulted insects of the same stadium could be identified in the original culture. Newly emerged adults were weighed singly, and the results recorded according to sex; standard errors of the mean weights of this stage were computed. The results are presented in Table I.

[1]Contribution No. 46, Canada Agriculture Research Station, Saskatoon, Saskatchewan.
[2]Entomologist and Technician, respectively.

TABLE I. Average weight, in milligrams, of newly emerged stages of some common grasshoppers of Western Canada

	Melanoplus dawsoni		*Camnula pellucida*		*M. bilituratus*		*M. packardii*		*M. bivittatus*	
Stage	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
1st instar	39	3.41	181	4.71	143	4.23	531	5.24	136	6.47
2nd	32	6.25	71	9.66	108	11.8	112	11.4	61	14.3
3rd	26	13.5	111	20.6	125	28.4	87	26.8	81	42.3
4th	24	27.0	94	45.2	86	54.7	70	65.2	73	94.3
5th	28	54.4	88	100	53	115	58	179	43	241
Adult										
Males	12	94.1 ±4.4	36	148 ±3.7	35	216 ±3.8	19	320 ±9.4	22	424 ±17.6
Females	14	117 ±5.7	31	223 ±5.9	21	231 ±6.9	24	365 ±11.9	16	665 ±38.6

The average increase in weight from instar to instar, in terms of the ratio of the weight at the beginning of a stadium to that at the beginning of the preceding one, tended to vary irregularly among the five such ratios available for each species studied. They were therefore averaged, to produce the following figures: *M. dawsoni*, 1.99; *C. pellucida*, 2.09; *M. bilituratus*, 2.23; *M. packardii*, 2.32; *M. bivittatus*, 2.44. The increasing trend of the ratio with increasing adult weight (Table I) will be noted. This trend does not extend to the old-world plague locusts such as *Locusta migratoria migratorioides* (R. & F.) which according to Duarte's data (1938) had an average growth progression factor of 2.38, and in which adult females weighed about 1275 mg. as opposed to 665 mg. in *M. bivittatus*. Similarly Bodenheimer (1929), Husain *et al.* (1946) and Davey (1954) show *Schistocerca gregaria* (Forsk.) increasing in weight from 18-33 mg. on hatching to 1.15-1.80 gm. on reaching the adult stage, the growth ratio between instars varying from 2.2 to 2.4. Thus, the species considered in this paper achieve their different adult weights by hatching weights and instar-to-instar growth ratios that are approximately correlated with the adult weights; the bigger old-world locusts attain their weights by relatively heavy hatching weights and growth ratios not in excess of the higher ones noted here.

Sexual dimorphism, expressed as the ratio of the weight of adult females to that of adult males, was as follows: *M. bilituratus*, 1.07; *M. packardii*, 1.14; *M. dawsoni*, 1.25; *C. pellucida*, 1.51, and *M. bivittatus*, 1.57.

The robustness of grasshoppers is susceptible to the influence of food and probably other environmental factors (e.g. Brett, 1947, and Pfadt, 1948). Since the grasshoppers dealt with in the present report were reared over a lengthy period, uniformity of food supplied was improbable. The average weights of newly emerged adult *M. bilituratus* reared by Smith (1958) on wheat seedlings was about 252 mg., more than that reported here for this species, and the cultures reared by Pfadt (1949) on favorable foods were still heavier. Further, there is evidence (Putnam, unpublished data) that grasshoppers of the same species from different sources may vary inherently in respect of weight. Average weights of sexually mature males of *M. bilituratus* from sources geographically widely separated, and reared simultaneously in the laboratory, differed by as much as 75 mg., and females by as much as 100 mg. The two-year life cycle biotype of *M. bivittatus* (Putnam and Handford, 1956) was over 100 mg. lighter on reaching the adult stage than the Saskatchewan material reported in Table I. A fully accurate characterization of the weights of these species

cannot be made, even for standard rearing conditions, without taking into consideration the possibility of intraspecific polymorphism. Nevertheless, the data in Table I may be taken as approximately indicative of what may be expected of the five species, and correctly indicative of their relative weight status.

Summary

The weights of newly emerged adult males and females of each of five common grasshopper species of Western Canada, together with ratios of female to male weights (brackets), were respectively: *Melanoplus dawsoni*, 94 and 117 mg.; (1.25); *Camnula pellucida*, 148 and 223 mg.; (1.51); *M. bilituratus*, 216 and 231 mg.; (1.07); *M. packardii*, 320 and 365 mg.; (1.14); and *M. bivittatus*, 424 and 665 mg.; (1.57). The average ratios of the weight at the beginning of any instar to that of the preceding one were respectively 1.99, 2.09, 2.23, 2.32 and 2.44 in the five species. The weights found in this study do not embrace the possibilities for variation due to environmental factors and intraspecific genetic differences.

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Notes on Drinking and the Need for Water in Orthoptera[1]

By S. K. GANGWERE

Introduction

The literature on Orthoptera (*sens. lat.*) includes a number of cursory notes describing laboratory drinking in various species, but an extended discussion of this behaviour is not available. The author has spent the past seven years studying the feeding behaviour of Michigan Orthoptera, during which time he has also made observations and conducted experiments on intake of water. Findings with respect to the latter, although of a preliminary nature, are given in the following paper.

Methods and Procedures

In the Laboratory. Series I: Behaviour in Absence of Water. During the course of experiments on food selection observations were made on thirty-seven species of caged Orthoptera which were denied access to water receptacles, thus furnishing data under comparatively dry conditions. It is assumed that these insects obtained needed unbound water from their supply of fresh, non-dry food, either leaves and flowers of herbs or pieces of meat and prey, whichever was appropriate for the species.

In the Laboratory. Series II: Behaviour in Presence of Water. In contrast, a second series of tests was made using most of the same species as used in Series I to see whether there was a modification of their behaviour in the presence of water. This time the insects were given both fresh, non-dry foods and water, the latter in a homeopathic vial plugged with cotton and placed on its side on the floor of the cage.

In the Field. Observations were carried out on forty-five species of uncaged Orthoptera, free in the field, where they were subject to natural conditions. These included all of the species observed in captivity, as listed below, except the domestic *Blattella germanica* and *Acheta domesticus.* A battery-operated headlamp was used for observations during darkness.

Results

In the Laboratory. Series I: Behaviour in Absence of Water. Individuals of the following species, which were not given water receptacles, were successfully maintained on fresh, non-dry foods for one to three months or more but were found to be unable to subsist, in absence of water, on dry foods, *e.g.*, bran flakes or chicken mash:

Blattidae (*sens. lat.*) (*cockroaches*)
Blattella germanica (L.)
Phasmatidae (*walking-sticks*)
Diapheromera femorata (Say)
Tetrigidae (*grouse locusts*)
Tetrix subulata (L.)
Tettigidea l. lateralis (Say)
Acrididae: *Acridinae*
(*slant-faced locusts*)
Chloealtis conspersa Harris
Chorthippus longicornis (*Latr.*)
Orphulella speciosa (Scudder)
Pseudopomala brachyptera (Scudder)
Syrbula admirabilis (Uhler)
Acrididae: *Oedipodinae*
(*band-winged locusts*)
Arphia p. pseudonietana (Thomas)
Arphia sulphurea (F.)
Camnula pellucida (Scudder)
Chortophaga viridifasciata (DeG.)
Dissosteira carolina (L.)
Encoptolophus s. sordidus (Burm.)
Pardalophora apiculata (Harris)
Spharagemon b. bolli Scudder
Spharagemon collare Scudder

[1]Contribution No. 32 from the Department of Biology, Wayne State University, Detroit 2, Michigan.

Acrididae: *Cyrtacanthacridinae*
(*spine-breasted locusts*)
Melanoplus b. bilituratus
(F. Walker)
Melanoplus bivittatus (Say)
Melanoplus confusus Scudder
Melanoplus f.-r. femur-rubrum
(DeG.)
Melanoplus keeleri luridus (Dodge)
Melanoplus s. scudderi (Uhler)
Paroxya hoosieri (Blatch.)
Schistocerca alutacea (Harris)
Tettigoniidae: *Phaneropterinae*
(*bush and round-headed katydids*)
Amblycorypha oblongifolia (DeG.)
Amblycorypha rotundifolia
(Scudder)
Scudderia c. curvicauda (DeG.)
Tettigoniidae: *Copiphorinae*
(*cone-headed katydids*)
Neoconocephalus ensiger (Harris)
Tettigoniidae: *Conocephalinae*
(*meadow grasshoppers*)
Conocephalus f. fasciatus (DeG.)
Orchelimum gladiator Bruner
Tettigoniidae: *Decticinae*
(*shield-bearers*)
Atlanticus testaceus (Scudder)
Gryllidae: *Gryllinae*
(*field crickets*)
Acheta domesticus (L.)
Acheta pennsylvanicus (Burm.)
Gryllidae: *Nemobiinae*
(*ground crickets*)
Nemobius f. fasciatus (DeG.)
Gryllidae: *Oecanthinae*
(*white tree crickets*)
Oecanthus nigricornis
quadripunctatus Beutenm.

In the Laboratory. Series II: Behaviour in Presence of Water. The results in this series were variable. When individuals of some species were given water they visited the receptacle regularly, pressing their mouthparts into the moist cotton for 30 seconds or more, although they had been given the appropriate kind of fresh, non-dry food-plants. Individuals of most, however, visited it sporadically if at all. *Chorthippus longicornis* and several other grasshoppers and katydids were observed imbibing droplets of water from plant leaves.

In the Field. Not once during the many hours in the field was an undisputed case of drinking observed, despite the fact that an effort was made to detect it and that over two hundred feeding records were obtained during this period.

Not only were the insects not observed to drink in nature, but some accepted foods so dry as to appear unpalatable. Several individuals of *Arphia sulphurea* were observed feeding on dry, brown oak (*Quercus*) leaves in the midst of large amounts of Canada bluegrass (*Poa compressa*), which is one of the species' common food-plants in southern Michigan. Other individuals of this species were seen eating dry grass leaves, including those of *Aristida purpurascens* and *Poa compressa*.

Additional species found feeding on desiccated foods include *Chloealtis conspersa*, eating dry leaves of strawberry (*Fragaria virginiana*) and poverty-grass (*Danthonia spicata*); a nymph of *Melanoplus f.-r. femur-rubrum*, those of goldenrod (*Solidago*); nymphs of *Scudderia c. curvicauda*, those of milkweed (*Asclepias syriaca*) and raspberry (*Rubus flagellaris*); a nymph of *Scudderia f. furcata*, those of swamp-birch (*Betula pumila*); *Orchelimum volantum*, those of the sedge *Carex;* and *Oecanthus niveus*, those of honeysuckle (*Lonicera*). Eating of dry flowers was observed in *Oecanthus n. nigricornis*, which took those of wild bergamot (*Monarda fistulosa*). Eating of dry bodies of animals was observed in a nymph of *Conocephalus brevipennis*, several of *Atlanticus testaceus*, and an adult of *Melanoplus confusus*, which took those of various insects, and in an adult of *Ceuthophilus brevipes*, which took the remains of an earthworm. Similar records were obtained from the laboratory studies.

Discussion

Observations were made on laboratory-caged *Chorthippus longicornis* and on certain other grasshoppers and katydids as they imbibed droplets of water from plant leaves, from the sides of their cages, or from water receptacles. Similar behaviour has been noted in the literature, which includes, among others, records for the following genera: the blattid *Periplaneta* (Leclercq, 1946; Rau, 1940); the mantids *Gongylus* (Williams, 1904) and *Sphodromantis* (Williams and Buxton, 1916); the phasmids *Carausius* (Roth, 1917), *Diapheromera* (Williams, 1907), and *Phyllium* (Leigh, 1909); the acridid *Nomadacris* (Albrecht, 1953); the rhaphidophorine *Typhloceuthophilus* (Hubbell, 1940); the bradyporine *Bradyporus* (Boldyrev, 1928); the decticine *Peranabrus* (Melander and Yothers, 1917); and the grylline *Acheta* (various workers, including Leclercq, 1946). In fact, almost every available account of rearing techniques of Orthoptera includes some provision for free water[2].

There has been some discussion concerning the role that drinking plays in the cricket *Acheta domesticus*. Haskell and Ives (1954) found that drinking water is essential in laboratory maintenance of the species. This is supported by Busvine (1955), who cited Kemper's contention that free water is needed to prevent cannibalism. Bunting (1954; 1955), however, found the opposite to be true, and Leclercq (1954) supported him. Leclercq said that these crickets can obtain moisture from a vegetable source, as has been reported in *Schistocerca gregaria* (Husain, Ahmad, and Mathur, 1940), and that they can grow successfully without drinking, but he pointed out the significant role that atmospheric moisture plays in the matter. Further, Jordan and Baker (1956) were able to maintain *A. domesticus* on slices of apple and apparently without a water receptacle. Evidence from the present study corroborates the views of Bunting, Leclercq, and Jordan and Baker.

The above, in general, suggests that Orthoptera may drink, but whether they actually do so in nature is still controversial. Although experiments have not been devised in the present study to prove or to disprove the occurrence of drinking in nature, most of the evidence, which is based on impressions gained over a long period, indicates that any assumption of regular drinking is probably not warranted.

During the detailed field investigations over seven years not a single instance of drinking by orthopterans was recorded. Because grooming, feeding, and mating coincide fairly closely with one another and with the insects' period of greatest activity, it would be expected that taking of food and of water, if any, would also coincide. If this is the case and if drinking were common, at least a few records should have been obtained during a period when over one hundred feeding records were compiled.

It might be argued that drinking records were not obtained in the field because water was seldom available. This is not true, for water was present after rainfall in the form of droplets on the vegetation and on the ground, and it was often present in the form of dew. During such times considerable field work was carried out. It might also be noted that, under these conditions, grasshoppers and their relatives are comparatively inactive (Gangwere, 1958) and, hence, probably would not drink if they did have such tendencies.

Certain of the feeding records are significant in another respect, for they show that many Orthoptera, while apparently not inclined to drink, are not even

[2]For an extensive list of articles on rearing, most of which include remarks on watering, the reader is referred to the author's paper on feeding and culturing (1960).

restricted to fresh, non-dry food materials, whether food-plants or prey, but often accept desiccated foods in the presence of ample amounts of fresh ones.

Thirty-seven species were successfully maintained without access to water receptacles and on a fresh, non-dry diet in the laboratory, where the humidity was comparatively uniform and seldom very high. With a few exceptions, there was no apparent increase in mortality. Even when filled water receptacles were introduced into the cages only a few species visited them regularly, except when there was an absence of fresh, non-dry food of a type appropriate for the species.

The data on the cockroach *Blattella germanica* and on the grouse locusts *Tettigidea l. lateralis* and *Tetrix subulata*, which require moist cage conditions, are subject to some error; although they were not given water in a receptacle they probably obtained it periodically from the sides and floor of their containers. There is also uncertainty about the white tree cricket *Oecanthus n. quadripunctatus* and the grasshopper *Pseudopomala brachyptera*. These species proved difficult to maintain, perhaps because they require greater humidity and a source of drinking water. This needs further investigation.

Summary

While a definitive statement cannot be made until more evidence is available, the present investigation leads one to conclude that drinking is probably rather uncommon among Michigan Orthoptera. It appears that individuals of most species do not drink regularly in nature, but depend on unbound water in their foods, even the drier types of which contain considerable amounts. It also appears that there are varying degrees of water need in the Orthoptera, for individuals of some species, *e.g.*, *Arphia sulphurea*, often accept dry foods in the presence of fresh, succulent ones, whereas a few others, including some Michigan species of cockroaches and grouse locusts, require considerable moisture and perhaps drink at frequent or infrequent intervals.

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Further Notes on the Genus *Masonaphis* Hille Ris Lambers, 1939 (Homoptera: Aphididae)[1]

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Hille Ris Lambers (1939) erected the genus *Masonaphis* with *Macrosiphum rhododendri* Wilson, 1918, as typus generis. When I revised this genus (1958) there was no opportunity to examine authentic material of the genotype. Since then Dr. A. A. Granovsky, University of Minnesota, Saint Paul, Minnesota, has kindly supplied to me cotype slide 2 of the species and cotype slide 5 to Miss L. M. Russell, United States Department of Agriculture, Washington, D.C. I have examined and remounted both slides which were labelled: *Macrosiphum rhododendri* n. sp.; Newport, Oregon; June 15, 1915; *Rhododendron californicum* leaves; H. F. Wilson; 509 cotype. Slide 2 contained sexuales and an alate viviparous female; slide 5 contained alate males and an apterous and an alate viviparous female. In addition Miss Russell provided me with material containing all morphs collected in Washington, Oregon, and California.

The descriptions of the alate and apterous viviparous females in MacGillivray (1958) fit the cotypes of the morphs that I examined. There are differences in certain measurements but these may be due to the generation involved. Because of these differences, measurements are given here of this additional material.

[1]Contribution No. 30, Research Station, Canada Department of Agriculture, Fredericton, New Brunswick.

Fundatrix

Measurements in mm.

No.	Length				Rhin. on III	Ant. segments			
	Body	Ant.	Siph.	Cau.		III	IV	V	VI
1	2.30	1.32	0.45	0.20	1 & 2	0.37	0.18	0.20	0.11 +0.28
2	?	1.39	0.51	?	1 & 1	0.36	0.19	0.20	0.11 +0.33

(1-2, from *Rhododendron*, C. F. Doucette; 1, Winchester Bay, Oregon, 28-V-1952; 2, Lakeside, Oregon, 5-VI-1952).

Apterous viviparous female

The examined cotype of the apterous viviparous female is smaller than any of those specimens which I previously examined, but its measurements are similar to those of number 16 as recorded by MacGillivray (1958, p. 32) and to number 9 below. Because of the additional specimens examined, slight alterations should be made in the 1958 description. Body 2.05-3.07 mm. long. Longest hairs on antennal segment three, 4/7 to 1⅓ times basal diameter of that segment; processus terminalis usually shorter than third antennal segment, sometimes slightly longer, usually less than five times base of sixth segment.

Measurements in mm.

No.	Length				Rhin. on III	Ant. segments			
	Body	Ant.	Siph.	Cau.		III	IV	V	VI
1	2.18	2.06	0.57	0.29	3 & 3	0.53	0.31	0.34	0.12+0.55
2	2.23	?	0.52	0.27	2 & ?	0.52	0.39	0.33	0.11+ ?
3	2.54	2.32	0.68	0.29	3 & 5	0.63	0.39	0.39	0.11+0.56
4	2.83	?2.62	0.71	0.34	4 & 5	0.74	0.45	0.47	0.15+0.55?
5	2.64	?	0.69	0.32	7 & 7	0.61	0.42	0.36	0.14+ ?
6	?	2.23	0.61	?	3 & 4	0.55	0.36	0.37	0.12+0.57
7	2.66	2.42	0.79	0.32	4 & 5	0.68	0.44	0.38	0.12+0.54
8	2.15	2.03	0.62	0.30	3 & 5	0.51	0.34	0.35	0.14+0.52
9	?	2.12	0.63	0.30	4 & 4	0.52	0.33	0.35	0.12+0.56
10	3.07	2.41	0.66	0.33	5 & 5	0.70	0.44	0.37	0.14+0.54
11	2.05	1.98	0.48	0.23	2 & 2	0.46	0.34	0.33	0.12+0.54

(1, cotype, from *Rhododendron californicum*, Newport, Oregon, 15-VI-1915, H. F. Wilson; 2-11, from *Rhododendron*, C. F. Doucette, 2-8, Lakeside, Oregon; 2, 18-VII-1953; 3-5, 6-VII-1955; 6, 7-VII-1950; 7-8, 19-VII-1951; 9-10, Langlois, Oregon, 3-VI-1952; 11, South of Crescent City, California, 18-VII-1952).

Alate viviparous female

The two alate viviparous females have longer siphunculi and cauda and shorter antennae compared with the one specimen described by MacGillivray (1958).

Measurements in mm.

No.	Length				Rhin. on III	Ant. segmnets			
	Body	Ant.	Siph.	Cau.		III	IV	V	VI
1	2.34	2.37	0.55	0.26	19 & 20	0.66	0.37	0.44	0.11+0.71
2	2.79	2.56	0.63	0.27	20 & 21	0.72	0.42	0.44	0.14+0.64

(1, cotype, from *Rhododendron californicum*, Newport, Oregon, 15-VI-1915, H. F. Wilson; 2, from *Rhododendron*, Lakeside, Oregon, 7-VII-1950, C. F. Doucette).

Oviparous female

Similar to the apterous viviparous female. Abdomen with smoky marginal sclerites. Siphunculi hardly swollen. Lateral rudimentary gonapophyses several times as large as the median one. Hind tibia swollen to about 1.3 times maximum diameter of middle tibia with some 60 to 85 pseudosensoria on basal two-thirds part.

Measurements in mm.

No.	Length				Rhin. on III	Ant. segments			
	Body	Ant.	Siph.	Cau.		III	IV	V	VI
1	2.54	2.16	0.58	0.24	4 & 5	0.55	0.36	0.37	0.13+0.52
2	1.90	1.77	0.47	0.19	2 & 3	0.44	0.27	0.33	0.09+0.45
3	1.93	1.72	0.43	0.16	3 & 3	0.42	0.28	0.30	0.10+0.45
4	2.10	1.92	0.45	0.21	3 & 4	0.50	0.33	0.33	0.10+0.50
5	2.50	?	0.52	0.26	3 & 4	0.50	0.34	0.37	0.10+ ?
6	2.24	2.07	0.51	0.26	2 & 4	0.51	0.35	0.38	0.11+0.51
7	?2.59	?	0.64	0.25	8 & ?	0.61	0.41	?	?
8	2.10	1.99	0.51	0.23	5 & 6	0.51	0.34	0.34	0.11+0.48

(1-2, cotypes, from *Rhododendron californicum*, Newport, Oregon, 15-VI-1915, H. F. Wilson; 3-8, from *Rhododendron*, Lakeside, Oregon, C. F. Doucette; 3-5, 18-VII-1953; 7, 7-VII-1950; 8, 6-VII-1955).

Alate male

Head and thorax brown; abdomen with rather large marginal sclerites, and with irregular spinal rectangular sclerites. Antennal segments three to five pale or evenly pigmented light brown with processus terminalis pale. Third antennal segment with along one side 42 to 61 scattered rhinaria; fourth segment with 0 to 16 rhinaria; fifth segment with 11 to 19 rhinaria along one side. Siphunculi short and slender, practically cylindrical. Cauda fingershaped, short, about three-sevenths of length of siphunculi.

Measurements in mm.

	Length				Rhin. on			Ant. segments			
No.	Body	Ant.	Siph.	Cau.	III	IV	V	III	IV	V	VI
1	2.23	?	0.38	0.14	48 & 53	0 & 0	16 & 16	0.73	0.48	0.57	0.15+ ?
2	2.14	2.82	0.37	0.16	52 & 61	0 & 0	17 & 17	0.73	0.49	0.52	0.11+0.77
3	2.09	3.00	0.41	0.14	44 & 45	9 & 13	16 & 18	0.85	0.47	0.53	0.13+0.78
4	2.07	2.95	0.38	0.17	55 & 57	1 & 4	19 & ?	0.66	0.52	0.56	0.15+0.86
5	?2.20	2.92	0.38	0.16	53 & ?	16 & ?	18 & ?	0.77	0.52	0.56	0.14+0.74
6	2.11	2.84	0.36	0.16	42 & 43	0 & 4	16 & 16	0.83	0.49	0.55	0.16+0.84
7	2.15	?	0.42	0.17	52 & 53	0 & 2	11 & 11	0.65	0.60	0.61	0.14+ ?

(1-6, cotypes, from *Rhododendron californicum*, New Port, Oregon, 15-VI-1915, H. F. Wilson; 7, from *Rhododendron*, Lakeside, Oregon, 18-VII-1953, C. F. Doucette).

From these additional records it is possible to speculate about the life history of the species. Fundatrices have been collected May 20, Crosby, Washington; May 28, Winchester Bay, Oregon; June 5, Lakeside, Oregon; and July 28, Zigzag Mountains, Oregon. Sexuales have been collected as early as June 15 at New Port, Oregon, and up to July 18 at Lakeside. As pointed out by MacGillivray (1958) some of the apterous viviparous females collected July 28 in the Zigzag Mountains had a few pseudosensoria on the hind tibiae and this collection

also contained fundatrices. It would seem that only one generation occurs between the fundatrix and the production of sexuales, considering the records from Zigzag Mountains and from Lakeside.

Soliman (1927) wrote that the alate morph described by Wilson (1918) was a male but Wilson's description and measurements appear to be based on both the alate female and alate male. His drawing of the third antennal segment is that of an alate female judging by the number of rhinaria pictured (sixteen). In his description he says that thirty to forty are present as is the case in the alate male.

***Masonaphis (Masonaphis) lambersi* sp. nov.**

In July, 1958, Miss Russell sent to me for identification four specimens of *Masonaphis* H.R.L. sensu stricto collected from *Rhododendron*, Sumner, Washington, May 18, 1958. These did not fit any species of *Masonaphis* known to me. The following description is based on this material and additional specimens collected in 1959.

Fundatrix

Like the following morph but broader. Antennae longer than body, light brown with apices of segments three, four and five, and all of six dark brown; processus terminalis about 3.4 times as long as base of sixth segment. Siphunculi swollen with distal 1/18 to 1/16 reticulated.

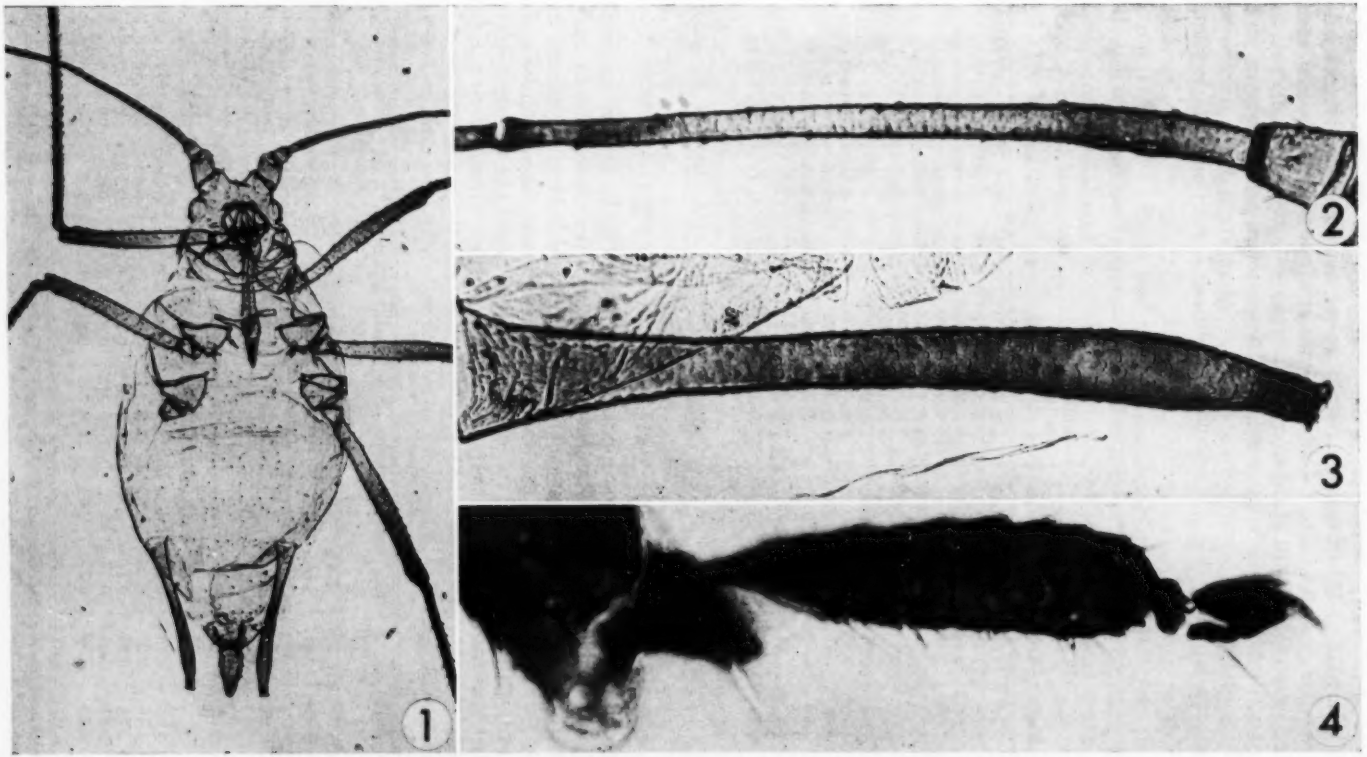
Measurements in mm.

Length					Rhin. on III	Ant. segments			
No.	Body	Ant.	Siph.	Cau.		III	IV	V	VI
1	2.70	2.89	0.88	0.36	2 & 4	0.74	0.52	0.50	0.20+0.68
2	2.52	2.84	0.84	0.36	4 & 4	0.84	0.47	0.50	0.18+0.62

(1-2, from *Rhododendron*, Long Beach, Washington, 20-V-1958, D. Cox).

Apterous viviparous female. (Fig. 1)

Colour in life unknown. Body spindle-shaped, 2.16 to 3.37 mm. long. Integumentum smooth. Dorsal hairs on third abdominal segment 2/9 to 3/7 of basal diameter of third antennal segment, those on eighth tergite 4/7 to 1 1/5 times that diameter. Small, flat tubercles sometimes present on eighth abdominal tergite with similar marginal tubercles on abdominal two and three. Head nearly smooth with a distinct median tubercle; frontal tubercles each with three to four hairs. Middle pair of hairs in posterior row on vertex 0.009 to 0.032 mm. long. Antennae subequal in length to body, segments one to four light brownish with the apices of three, four, and five and all of six dark brown; first segment slightly imbricated on inner and outer sides, second segment imbricated ventrally, flagellum imbricated throughout; but sometimes third segment only very weakly imbricated; third segment (Fig. 2) with two to six rhinaria in a row on basal two-sevenths part (or in an aptera with ocelli 19 and 21 in a straight row over the length of the segment); longest hairs on third segment 1/4 to 3/7 of basal diameter of that segment. Rostrum reaching to hind coxae; last segment 0.14 to 0.16 mm. long, 1.4 to 1.9 times as long as second joint of hind tarsus, with 15 to 23 hairs besides the three apical pairs. Siphunculus (Fig. 3) light to dark brown with basal one-third pale; swollen at distal one-quarter part up to 1.6 times smallest diameter basad (the latter 1.1 to 1.3 times as wide as maximum



Figs. 1-4. *Masonaphis* (*Masonaphis*) *lambersi* nov. spec., apterous viviparous female. 1, Apterous viviparous female. 2, Third antennal segment. 3, Siphunculus. 4, Second joint of hind tarsus showing spinules.

thickness of hind tibia), distad the swelling narrowing to the reticulated area which is about 3/7 to 3/4 of the maximum diameter and then widening towards the flange which is about 1.2 to 1.6 times as wide as the reticulated area; at apex reticulated over 1/27 to 1/10 of the length, remainder imbricated. Cauda pale to light brown, slender, hardly constricted, with six or seven, rarely eight or nine hairs. Legs pale to light brown with apices of tibiae and tarsi darker, tarsi with very small second joints (Fig. 4), spinulosely imbricated, with on the first joints five hairs.

Measurements in mm.

Length					Rhin. on III	Ant. segments			
No.	Body	Atn.	Siph.	Cau.		III	IV	V	VI
1	3.26	3.09	0.98	0.43	4 & 6	0.89	0.59	0.51	0.15+0.74
2	2.62	2.38	0.73	0.33	3 & 3	0.64	0.36	0.39	0.14+0.63
3	2.51	3.02	0.79	0.34	5 & 5	0.74	0.60	0.53	0.16+0.75
4	2.68	2.86	0.79	0.34	19 & 21	0.79	0.52	0.51	0.15+0.68
5	2.39	?	0.71	0.29	4 & 5	0.63	0.38	0.38	0.15+ ?
6	2.48	?	0.87	0.38	3 & 5	0.90	0.60	0.56	0.15+ ?
7	2.45	2.50	0.65	0.33	3 & 3	0.66	0.37	0.41	0.16+0.69
8	2.44	2.37	0.70	0.33	1 & 2	0.65	0.42	0.38	0.12+0.60
9	2.75	2.57	0.81	0.36	2 & 4	0.69	0.44	0.44	0.14+0.68
10	2.71	?	0.77	0.36	3 & 3	0.74	0.45	0.46	0.14+ ?
11	2.60	2.93	0.86	0.35	2 & 2	0.79	0.53	0.53	0.15+0.71
12	2.16	?	0.72	0.33	3 & 4	0.75	0.46	0.47	0.15+ ?
13	3.00	?	0.79	0.36	4 & ?	0.71	0.42	0.46	0.15+ ?
14	2.59	2.82	0.72	0.36	2 & 2	0.77	0.47	0.46	0.15+0.73

(1-14, from *Rhododendron;* 1, Sumner, Washington, 18-V-1958, C. F. Doucette; 2-14, Puyallup, Washington, 25-VII-1959, E. P. Breakey).

Alate viviparous female

Rather like the preceding morph. Abdomen with large brown marginal sclerites and small, faint pleural intersegmental spots. Antennae light to dark brown with base of third segment pale; third segment with 21 to 30 rhinaria in a more or less straight line over the length of the segment. Siphunculi light to dark brown with about the basal two-sevenths paler. Legs light to dark brown with basal one-third of femur paler. Wing veins normal, brown, very faintly shadowed.

Measurements in mm.

Length					Rhin. on III	Ant. segments			
No.	Body	Ant.	Siph.	Cau.		III	IV	V	VI
1	3.15	3.34	0.96	0.38	23 & 25	0.87	0.70	0.57	0.16+0.80
2	3.14	3.32	0.93	0.35	25 & 29	0.86	0.68	0.56	0.18+0.81
3	2.86	3.00	0.70	0.35	23 & 24	0.81	0.54	0.51	0.15+0.78
4	2.30	?	0.68	0.29	24 & 24	0.75	0.54	?	?
5	?	?	0.69	0.26	24 & 26	0.68	0.51	0.48	0.12+ ?
6	2.42	?	0.73	0.30	23 & 25	0.74	?	?	?
7	2.86	?	0.71	0.30	23 & 24	0.83	0.54	0.48	0.15+ ?
8	2.45	2.87	0.73	0.32	21 & 22	0.68	0.59	0.52	0.17+0.70
9	2.81	3.07	0.78	0.30	27 & 30	0.82	0.60	0.51	0.14+0.80
10	2.68	3.29	0.75	0.35	27 & 27	0.87	0.61	0.54	0.16+0.90
11	2.83	2.98	0.73	0.33	23 & 24	0.84	0.52	0.47	0.15+0.78

(1-11, from *Rhododendron;* 1-2, Sumner, Washington, 18-V-1958, C. F. Doucette; 3-11, Puyallup, Washington, 25-VII-1959, E. P. Breakey).

Notes. This is the species referred to by Knowlton (1954) as *Amphorophora rhokalaza* Tissot and Pepper, collected from *Rhododendron*, Long Beach, Washington, 20-VII-1948, C. Johansen. I have examined this material containing a much damaged alate female and two alatiform apterae, but because of their poor condition, I have not included measurements.

Types.–Holotype, apterous viviparous female, from *Rhododendron*, Puyallup, Washington, 25-VII-1959, E. P. Breakey, in the United States National Museum, Washington, D.C. *Paratypes*, data same as holotype, in the United States National Museum and in the Canadian National Collection of Insects. *Morphotypes*, alate viviparous female, data same as for holotype; fundatrix, from *Rhododendron*, Long Beach, Washington, 20-V-1958, D. Cox, in the United States National Museum.

My key to the subgenus *Masonaphis* Hille Ris Lambers, 1939, apterous viviparous females (Temminckia X, 1958, p. 26-27) should be altered as follows:

3 (4) Hairs on third antennal segment inconspicuous and short, longest hairs less than one-half basal diameter of that segment. Siphunculi with basal one-third paler than remainder, distinctly swollen, with a narrow stem; swollen to 1.3 to 1.6 times the narrow portion basad which is only 1.1 to 1.3 times the widest diameter of hind tibia. On *Rhododendron* ..... *M. (Masonaphis) lambersi* nov. spec.

4 (3) Hairs on third antennal segment conspicuous, longest hairs over one-half basal diameter of that segment. Siphunculi dark brown or pale throughout hardly swollen, swollen up to 1.1 times the narrowest portion basad which is usually more than 1.3 times widest diameter of hind tibia.

5 (6) Antennae considerably shorter than body, with processus terminalis less than five times base of sixth antennal segment; segments three, four, and five pale with apices dark. Siphunculi more or less pale. On *Rhododendron* ..... *M. (Masonaphis) rhododendri* (Wilson)

6 (5) Antennae longer than body, with processus terminalis usually more than six times base of sixth antennal segment; segments three, four, and five mostly dark, evenly pigmented. Siphunculi dark. On *Rhododendron* and *Kalmia latifolia* ..... *M. (Masonaphis) rhokalaza* (Tissot and Pepper)

Acknowledgments

I wish to thank Mr. D. Hille Ris Lambers, Bennekom, Netherlands for criticizing this manuscript and for allowing me to name the new aphid from *Rhododendron* in his honour.

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Taxonomy of Cocoons and Puparia, and their Contents, of Canadian Parasites of *Diprion hercyniae* (Htg.) (Hymenoptera: Diprionidae)

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INTRODUCTION

This is the second in a series of papers on the taxonomy of the cocoons and puparia, cast larval skins, and other remains of parasitic Hymenoptera and Diptera that are found in or near the remains of parasitized hosts after the parasites have emerged. The structures of taxonomic significance in the separation of the species were described and discussed in a previous paper (Finlayson, 1960). The present paper deals with the known Canadian parasites of the European spruce sawfly, *Diprion hercyniae* (Htg.). Parasites of *D. hercyniae* that were dealt with in the previous paper are not described or illustrated here.

MATERIALS AND METHODS

The materials and methods used were similar to those referred to by Finlayson (1960). Most of the records and specimens were from the individual rearing at the Entomology Research Institute for Biological Control, Belleville, Ont. of more than 1,448,000 cocoons of *D. hercyniae* collected in Quebec and New Brunswick from 1937 to 1941. Additional specimens were obtained from the Canadian National Collection in the Entomology Research Institute, Ottawa, Ont., and from the Forest Biology Laboratory, Fredericton, N.B.

The terminology used here is the same as that described and illustrated by Finlayson (1960) and largely follows that of Short (1952).

DIPRION HERCYNIAE AND ITS PARASITES

The European spruce sawfly, *D. hercyniae*, was first found in Canada in 1930 in the Gaspé Peninsula, Que., and during the succeeding ten years spread rapidly over wide areas of Eastern Canada (see Baird, 1937; Balch, 1937). The parasite species dealt with in this paper were listed as parasites of *D. hercyniae* in Canada by Baird (1939, 1941), Cushman, (1939), Dowden (1939), Finlayson and Finlayson (1958a), Hawboldt (1947), Martineau (1959), Peck (1951), Peirson (1941), Peirson and Nash (1940), Raizenne (1957), Reeks (1938, 1952, 1953), Thompson (1944), and Townes and Townes (1951).

Of the 32 species known to be recorded in the literature as parasites of *D. hercyniae* in Canada, 13 are described and illustrated in this paper, 15 were described and illustrated by Finlayson (1960) and four are omitted as cocoons from which they emerged were not available for study. These latter were *Mesochorus* sp., recorded by Raizenne (1957), and *Hemiteles* sp. and *Tritneptis hemerocampae* Grlt., recorded by Reeks (1938), in the Hymenoptera; and "*Megaselida*" (*Megaselia*) sp., recorded by Reeks, in the Diptera.

The 28 species included in the key consist of 18 species of 10 genera and four subfamilies, of the family Ichneumonidae of the Ichneumonoidea, and five species of five genera and three families of the Chalcidoidea in the Hymenoptera; and five species of five genera and one family, in the Diptera.

KEY TO PARASITES BASED ON COCOONS OR PUPARIA AND THEIR CONTENTS

1. Host cocoon not containing parasite puparium or cocoon 2
   Host cocoon containing parasite puparium or cocoon 9

2. Exit hole 1.3 mm. to 2.4 mm. in diameter; remains of a single parasite in host cocoon 3
   Exit hole 0.5 mm. to 1.1 mm. in diameter; remains of a few to many parasites in host cocoon 5
3. Larval skin of host round and hollowed out 4
   Larval skin of host not round and hollowed out (Fig. 12) *Bessa harveyi* (Tns.) p. 936
4. Exit hole about 1.3 mm. in diameter, edge curled outward slightly; cephalic structure of penultimate larval instar dipterous, as in Fig. 13 *Drino* (*Prosturmia*) *bohemica* Mesn. p. 937
   Exit hole about 2.4 mm. in diameter, edge not curled outward; cephalic structure of last larval instar hymenopterous, as in Fig. 1 *Pimpla pedalis* Cress. p. 925
5. Cast skin of last larval instar densely covered with long hairs or setae *Monodontomerus dentipes* (Dalm.) p. 934
   Cast skin of last larval instar not covered with long hairs or setae 6
6. Cephalic structure of last larval instar with only the mandibles visible 7
   Cephalic structure of last larval instar with mandibles, epistoma, pleurostomae, superior and inferior mandibular processes, and reduced hypostomae visible *Tritneptis* spp. p. 936
7. Large, cone-shaped antennae present (Figs. 11, 24) *Amblymerus verditer* (Nort.) p. 934
   Antennae not visible 8
8. Atrium of spiracle with about four divisions; secondary parasite *Dibrachys cavus* (Wlkr.) p. 936
   Atrium of spiracle with about ten to 14 divisions; usually primary parasite *Dahlbominus fuscipennis* (Zett.) p. 934
9. Host cocoon containing puparium; exit hole at tip of cocoon 10
   Host cocoon containing cocoon; exit hole usually slightly to side of tip 12
10. Exit hole with edge sharply cut, usually with hinged lid 11
    Exit hole with edge tapered and curled outward, to give a pushed-out appearance, without hinged lid *Spathimeigenia spinigera* Tns. p. 938
11. Length of mandibular hooks plus intermediate sclerite less than half total length of buccopharyngeal armature; distance from tip of hooks to postero-dorsal angle only slightly longer than distance from postero-dorsal angle to ventral projection of hooks *Diplostichus hamatus* (A. & W.) p. 937
    Length of mandibular hooks plus intermediate sclerite more than half total length of buccopharyngeal armature; distance from tip of hooks to postero-dorsal angle almost twice distance from postero-dorsal angle to ventral projection of hooks *Neophorocera edwardsii* (Will.) p. 938
12. Host cocoon containing a partial parasite cocoon *Delomerista diprionis* Cush. p. 924
    Host cocoon containing a complete parasite cocoon 13
13. Parasite cocoon flattened; exit hole well to side of tip *Mastrus argeae* (Vier.) p. 930
    Parasite cocoon rounded; exit hole just off tip 14
14. Labial sclerite closed dorsally *Delomerista diprionis* Cush. p. 924
    Labial sclerite open dorsally 15
15. Medial end of each stipital sclerite touching top of dorsal arm of labial sclerite 16
    Medial end of each stipital sclerite not touching top of dorsal arm of labial sclerite 18
16. Labial sclerite broken ventrally, without dorsal projection from ventral part *Lamachus* sp. p. 934
    Labial sclerite complete ventrally, with dorsal projection from ventral part 17
17. Mandibles each shorter and wider with narrower blade meeting body of mandible at an angle slightly greater than right angle; each dorsal arm of labial sclerite with conspicuous lateral projection, medial part only slightly serrated and meeting ventral part of arm at a sharp angle (Figs. 9, 22) *Mesoleius tenthredinis* Morl. p. 933
    Mandibles each longer and narrower with wide blade meeting body of mandible at an angle much greater than right angle; each dorsal arm of labial sclerite without conspicuous lateral projection, medial part heavily serrated and curving to meet ventral part of arm (Figs. 10, 23) *Mesoleius* sp. (possibly *viduus* Hgn.) p. 934
18. Epistomal arch incomplete, or appearing incomplete; labral sclerite present; blade of each mandible with two rows teeth 19
    Epistomal arch complete; labral sclerite absent; blades of mandibles without teeth 25
19. Blade of each mandible with tooth-like projection on posterodorsal side *Endasys subclavatus* (Say) p. 930
    Blade of each mandible without such projection 20
20. Blade of each mandible with two rows very fine, even teeth 21
    Blade of each mandible with two rows large, uneven teeth 22

21. Labral sclerite turns medially at almost a right angle at each end; dorsal arms of labial sclerite straight and same width for entire length (Figs. 6, 19) ..... *Gelis urbanus* Brues p. 930
Labral sclerite turns medially gently at each end; dorsal arms of labial sclerite enlarged ..... *Mastrus argeae* (Vier.) p. 930
22. Labral sclerite turns medially at each end at almost a right angle; antenna large, cone-shaped (Figs. 8, 21) ..... *Agrothereutes abbreviator similaris* (Prov.) p. 932
Labral sclerite not turning medially at each end at almost a right angle; antenna about the same width at top as at base 23
23. Length of hypostomal spur about four to five times width at base; blade of mandible swollen at bases of teeth; labral sclerite with vacuoles dorsally; epistoma complete, but appearing incomplete because unsclerotized 24
Length of hypostomal spur about seven times width at base; blade of mandible not or little swollen at bases of teeth; labral sclerite without apparent vacuoles dorsally; epistoma apparently incomplete ..... *Aptesis indistincta* (Prov.) p. 932
24. Each stipital sclerite meeting labial sclerite at angle greater than right angle; small protuberances present around antennal socket; labial sclerite with dorsal arms relatively narrower, ventral part rounded (Figs. 7, 20) ..... *Aptesis subguttatus* (Grav.) p. 932
Each stipital sclerite meeting labial sclerite at angle equal to or less than right angle; small protuberances absent around antennal socket; labial sclerite with dorsal arms relatively wider, ventral part flattened ..... *Aptesis basizona* (Grav.) p. 930
25. Hypostomal arms lacking; ventral portion of labial sclerite greatly thickened; hypostomal spurs each resting on medial end of reduced stipital sclerite close to labial sclerite (Figs. 1, 14) ..... *Pimpla pedalis* Cress. p. 925
Hypostomal arms present; ventral portion of labial sclerite not greatly thickened; hypostomal spurs each resting on central part of large stipital sclerite at short distance from labial sclerite 26
26. Each hypostoma with indentation on medial side of distal end; blade of mandible about 0.034 mm. long by 0.011 mm. wide at base (Figs. 3, 16) ..... *Exenterus affinis* Roh. p. 928
Each hypostoma lacking indentation on medial side of distal end; blade of mandible more than 0.034 mm. long by 0.011 mm. wide at base 27
27. Labial sclerite with dorsal arms not or very little enlarged, ventral portion with slight medial enlargement; blade of mandible on the average about 0.052 mm. long by 0.024 mm. wide at base (Figs. 2, 15) ..... *Exenterus confusus* Kerr. p. 926
Labial sclerite with dorsal arms enlarged, ventral portion of uniform thickness; blade of mandible about 0.043 mm. long or less and 0.018 mm. wide at base, or less 28
28. Hypostomal spur more than twice as long as its basal width 29
Hypostomal spur less than twice as long as its basal width 30
29. Height of epistomal arch above blades of mandibles about one-half its width at widest point; atrium of spiracle tapering to stalk—*Exenterus amictorius* (Panz.) p. 926
Height of epistomal arch above blades of mandibles a little more than one-third its width at widest point; atrium of spiracle wider than deep ..... *Exenterus canadensis* Prov. p. 926
30. Each hypostoma extending to about ventral margin of labial sclerite and turning medially at end (Figs. 5, 18) ..... *Exenterus vellicatus* Cush. p. 928
Each hypostoma extending below ventral margin of labial sclerite and not turning medially at end (Figs. 4, 17) ..... *Exenterus tricolor* Rom. p. 928

DESCRIPTIONS

HYMENOPTERA

Ichneumonoidea: Ichneumonidae

Pimplinae: Ephialtini

Delomerista diprionis Cush.

Delomerista diprionis Cush. was reported as a parasite of *D. hercyniae* by Cushman (1939), Peirson (1941), and Townes and Townes (1951), and was described and illustrated by Finlayson (1960) and Short (1959).

Pimplinae: Pimplini

***Pimpla pedalis* Cress.**

Figs. 1, 14

Pimpla pedalis Cress. was recorded as a parasite of *D. hercyniae* by Peirson (1941), Peirson and Nash (1940), and Townes and Townes (1951), and was reared at Belleville, Ont. from cocoons collected at Nouvelle, Que. Townes and Townes listed a large number of hosts, mainly lepidopterous, the only other sawfly being *Neodiprion* sp.

Exit hole almost on tip of cocoon, irregular in outline, about 2.4 mm. in diameter. No evidence of cocoon in specimens examined; larval skin of host seems to take place of parasite cocoon, suggesting this species is internal parasite. Larval remains are free in larval skin of host at end opposite exit hole.

Cephalic structure of last larval instar (Fig. 1) heavily sclerotized. Epistoma complete, joining with pleurostomae and hypostomal spurs to form circle broken only by labial sclerite. Heavy superior mandibular processes each articulate almost half-way down articulating surface of mandible; each inferior mandibular process thick-set, blunt, with central concavity for bulbous articulation of mandible. Hypostomal arms lacking; indentation present in region where the hypostoma would normally arise; lacinial sclerite absent. Each hypostomal spur long, heavy, resting on medial end of reduced stipital sclerite close to labial sclerite. Labial sclerite greatly thickened ventrally with each arm widening dorsally. Silk press lightly sclerotized, almost indistinguishable; prelabial sclerite not apparent. Labral sclerite absent. Mandible large with protuberance on caudal face visible through mandible; heavy, curved blade without teeth, with projection on dorsal edge. Large teeth visible under blades of mandibles in region of hypopharynx. Maxillary and labial palpi each with two or more sensoria. Numerous setae on labrum. Antenna small. Skin covered with minute spicules, occasional setae, numerous sharp bristles at caudal end. Atrium of spiracle (Fig. 14) round with projections radiating from walls to centre; very small opening from atrium to short, thick stalk made up almost entirely of closing apparatus.

Tryphoninae: Exenterini

Six species of *Exenterus* have been recorded from *D. hercyniae* in Canada, namely: *E. affinis* Roh., *E. amictorius* (Panz.), *E. canadensis* Prov., *E. confusus* Kerr., *E. tricolor* Rom., and *E. vellicatus* Cush. All except *E. affinis* and *E. canadensis* are European species that were liberated in Canada in attempts to control the European spruce sawfly, *D. hercyniae* (Finlayson and Finlayson, 1958a, 1958b).

Of a total of 14,203 *Exenterus* spp. reared at Belleville, Ont. in 1940 from cocoons of *D. hercyniae* collected at Parke Reserve, Que., and North Tay, N.B., 53.84 per cent were *E. confusus*, 46.12 per cent *E. amictorius*, 0.02 per cent *E. tricolor*, and 0.02 per cent *E. vellicatus*. Proportions have changed since that time (Balch, 1960), but most identifications involving this genus probably will be to separate *amictorius*, *confusus*, and *vellicatus*. Referring to the key it will be seen that *confusus* can be fairly readily separated from the other two species by the shape of the labial sclerite and the size of the blades of the mandibles. Sometimes there is difficulty in determining the relationship between length and basal width of the hypostomal spur in *amictorius*. The key is not infallible and in a test there was about 15 per cent error in separating *tricolor* and *vellicatus*.

Short (1959) described and illustrated *Exenterus canadensis* Prov. as having a labral sclerite. The present writer has examined many slides of specimens of

eight species of *Exenterus* and has been unable to find this structure. When the skin of the head capsule of this genus is flattened by a microscopic cover glass it assumes a rounded appearance over the top of the head and around the mandibles and often gives the appearance of a band in that region. It is thought this may have been mistaken for a labral sclerite. As the primary purpose here is to identify the parasite species found on *D. hercyniae* in Canada, and as the material examined does not lead to a change of opinion, the species in this paper, as in the previous one (Finlayson, 1960) are shown without a labral sclerite.

Exenterus amictorius (Panz.)

Exenterus amictorius (Panz.) was recorded as a parasite of *D. hercyniae* by Baird (1941), Raizenne (1957), Reeks (1952, 1953), and Townes and Townes (1951), and was described and illustrated by Finlayson (1960).

An additional characteristic used in the present paper is that blades of mandibles each average about 0.039 mm. long by 0.014 mm. wide at base.

Exenterus canadensis Prov.

Exenterus canadensis Prov. was recorded as a parasite of *D. hercyniae* by Townes and Townes (1951), and was described and illustrated by Finlayson (1960) and Short (1959).

An additional character used in the present paper is that blades of mandibles each average about 0.043 mm. long by 0.016 mm. wide at base.

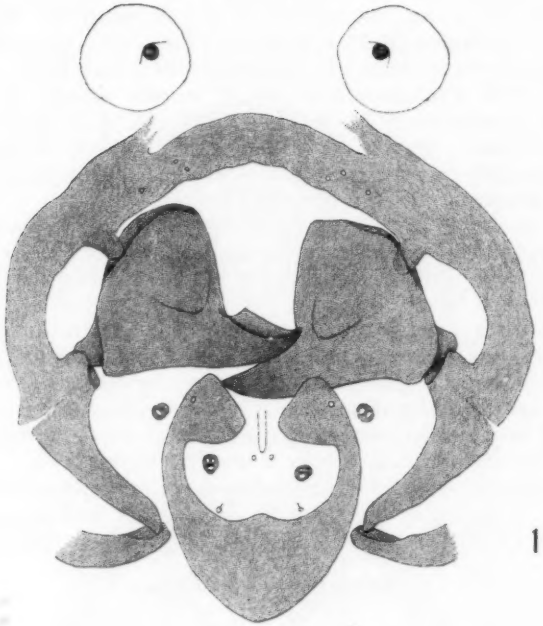
Exenterus confusus Kerr.

Figs. 2, 15

Exenterus confusus Kerr. was recorded as a parasite of *D. hercyniae* by Raizenne (1957), Reeks (1952, 1953) (as *E. claripennis* Thoms.), Townes and Townes (1951) (as *E. claripennis*), and of *Neodiprion nanulus nanulus* Schedl by Underwood (1960). It was reared at Belleville in large numbers from *D. hercyniae* cocoons collected at Parke Reserve, Que., and distributed to other areas.

Exit hole just off tip of host cocoon, irregular in outline, about 2.3 mm. in diameter. Parasite cocoon conforms in size and shape to host cocoon, but smaller; light rust to whitish, thin, fairly transparent, fuzzy on outside. Remains of last larval instar in meconium at end of cocoon opposite exit hole. One specimen was found without cocoon; in this case meconium and remains of last larval instar were fastened to host remains at end opposite exit hole.

Cephalic structure of last larval instar (Fig. 2) with complete epistoma; arch at widest point more than twice its height above blades of mandibles. Inferior mandibular processes each with two long struts; lacinial sclerite present. Length of hypostomal spur about twice its basal width. Each hypostoma extends slightly below level of labial sclerite. Stipital sclerites each large, meeting labial sclerite at right angle, extending well up dorsal arm at one end and to hypostoma at other. Labial sclerite with dorsal arms not or slightly enlarged, ventral portion with slight medial enlargement. Silk press long, narrow, lightly sclerotized. Pigmented area with fine teeth visible in region of upper central portion of labial sclerite. Mandible with large blade averaging about 0.052 mm. long by 0.024 mm. wide at base, without teeth. Maxillary and labial palpi each with one large, one small sensorium. Antenna small, papilla-like. Atrium of spiracle (Fig. 15) cup-shaped with reticulations, leading into short stalk with about five annulations and thick-walled closing apparatus. Skin covered with small spines, a few short setae.



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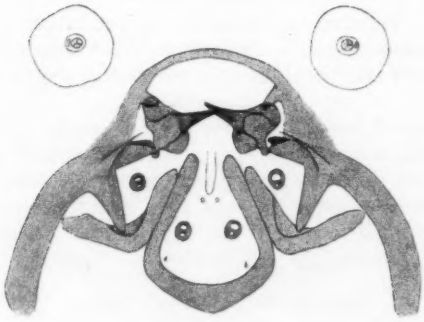

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0.1 mm.

Figs. 1-2. Cephalic structures of final-instar hymenopterous larvae: 1, *Pimpla pedalis* Cress.; 2, *Exenterus confusus* Kerr.

Exenterus affinis Roh.

Figs. 3, 16

Exenterus affinis Roh. was found to be a parasite of *D. hercyniae* in the Maritime Provinces by various officers of the Forest Insect Survey, Canada Department of Agriculture (B. M. McGugan, *in litt.*). It was recorded as a parasite of *Neodiprion abietis* (Harr.) by Cushman (1943) and Townes and Townes (1951); of *N. pratti banksianae* Roh. and *N. nanulus nanulus* by Townes and Townes; of *N. swainei* Midd. by Walley (1933); and of *N. virginiana* Roh. by Townes and Townes. Dr. W. R. M. Mason, Entomology Research Institute, Ottawa, indicated an opinion that this is a rare species that probably would be encountered infrequently as a parasite of *D. hercyniae*.

Exit hole to side of tip; round, fairly regular in outline; about 2.3 mm. in diameter. Parasite cocoon conforms in size and shape to host cocoon; transparent, whitish, very thin. Remains of last larval instar in meconium at end of cocoon opposite exit hole.

Cephalic structure of last larval instar (Fig. 3) similar to *E. confusus* except that labial sclerite has enlarged dorsal arms, ventral portion of uniform thickness; blade of mandible small, about 0.034 mm. long by 0.011 mm. wide at base; hypostomal spurs each more than twice as long as width at base; stipital sclerites each long and very slender; atrium of spiracle (Fig. 16) large with only a few reticulations, opening into stalk with six or seven annulations.

Can be separated from all other species in the same genus discussed in this paper by the indentation in medial side of distal end of each hypostoma, by the relatively small blade of mandible, and by the length of the stalk of spiracle.

Exenterus tricolor Rom.

Figs. 4, 17

Exenterus tricolor Rom. was recorded as a parasite of *D. hercyniae* by Reeks (1952, 1953) and was reared at Belleville, Ont. from cocoons collected at Parke Reserve, Que. in 1940.

Exit hole to side of tip; more jagged, irregular than for *E. confusus;* about 2.2 mm. in diameter. Parasite cocoon similar in size, shape, to host cocoon, but smaller; whitish in colour; thinner, more transparent than either *E. confusus* or *E. vellicatus;* remains of last larval instar in meconium at end of cocoon opposite exit hole.

Cephalic structure of last larval instar (Fig. 4) similar to *E. confusus* except that dorsal arms labial sclerite enlarged, ventral portion of uniform thickness; blade of mandible short and stout, averaging about 0.038 mm. long by 0.018 mm. wide at base; hypostomae usually do not turn medially at each end; epistomal arch at widest point about two and one-half times its height above blades of mandibles; atrium of spiracle (Fig. 17) similar to *E. confusus* but slightly smaller.

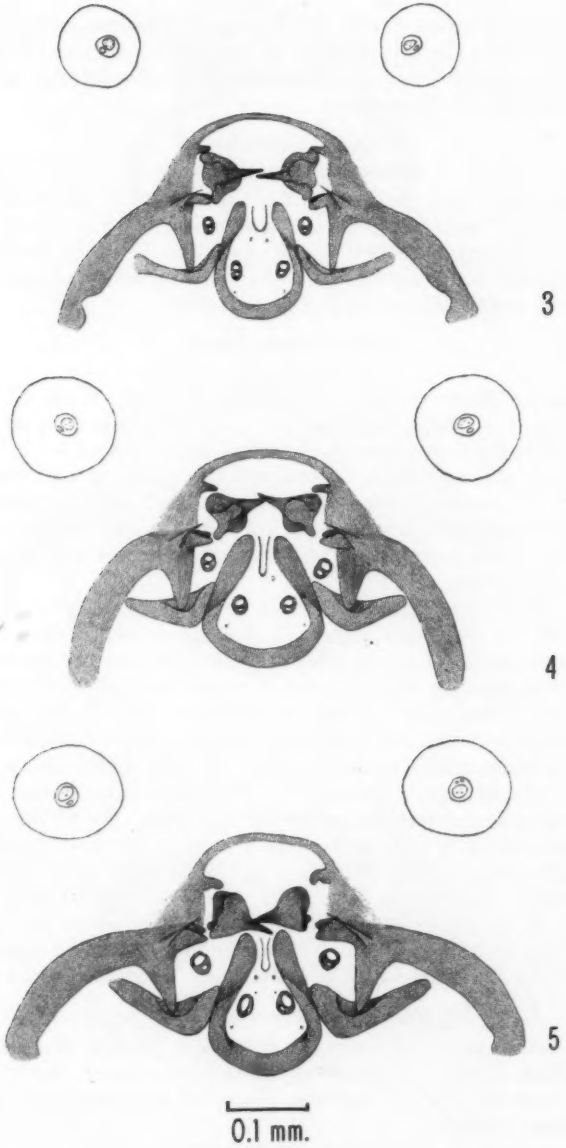
Exenterus vellicatus Cush.

Figs. 5, 18

Exenterus vellicatus Cush. was recorded as a parasite of *D. hercyniae* by Reeks (1952, 1953) and was reared at Belleville, Ont. from cocoons collected at North Tay, N.B., in 1940.

Exit hole just off tip of host cocoon, more irregular than for *E. confusus*, about 2.3 mm. in diameter. Parasite cocoon rusty-brown; thin, transparent, slightly fuzzy on outside.

Cephalic structure of last larval instar (Fig. 5) as for *E. confusus* except that labial sclerite has widened dorsal arms, ventral portion of uniform thickness;



Figs. 3-5. Cephalic structures of final-instar hymenopterous larvae: 3, *Exenterus affinis* Roh.; 4, *E. tricolor* Rom.; 5, *E. vellicatus* Cush.

blade of mandible averaging 0.038 mm. long by 0.016 mm. wide at base; epistomal arch at widest point about one and one-half times its height above blades of mandibles.

Differs from *E. tricolor* in that the hypostomae seldom extend below labial sclerite, and each turns slightly medially at distal end. Atrium of spiracle (Fig. 18) cup-shaped, opening into stalk with about five annulations, strong closing apparatus; smaller than in *E. confusus*.

Cryptinae: Hemitelini

Mastrus argeae (Vier.)

Mastrus argeae (Vier.) was recorded as a parasite of *D. hercyniae* by Peirson (1941), Peirson and Nash (1940) (as *M. neodiprioni* (Vier.)), Reeks (1938) (as *M. neodiprioni*), Thompson (1944) (as *M. aciculatus* (Prov.)), and Townes and Townes (1951), and was reared in Belleville from cocoons collected in Quebec. It was described and illustrated by Finlayson (1960).

Gelis urbanus Brues

Figs. 6, 19

Gelis urbanus Brues was reared in Belleville, Ont. from cocoons of *D. hercyniae* collected at Parke Reserve, Que. in 1940. It is a hyperparasite, the primary parasite being *E. confusus* in the specimens examined.

Exit hole on side of cocoon, toward tip, or to side of tip; round, regular; about 1.2 mm. in diameter. Cocoon oval in shape, much smaller than host cocoon; beige-white with a few blackish fibres on outside; loosely-woven, fairly thick. Remains of last larval instar free near meconium at end of hyperparasite cocoon opposite exit hole.

Cephalic structure of last larval instar (Fig. 6) with incomplete epistoma. Superior mandibular processes each well developed; each inferior mandibular process with two struts. Lacinial sclerite present but not conspicuous. Hypostomal arm short, curving laterally and abruptly ventrally. Hypostomal spur long, heavy, about four times as long as width at base. Dorsal arms of labial sclerite straight, same width for their entire length. Stipital sclerites each touch labial sclerite at about middle of dorsal arm, with only slight bend upward. Silk press widely U-shaped, lightly sclerotized. Prelabial sclerite absent. Two small, heavily-sclerotized areas lateral and ventral to silk press. Mandibles with straight blade with two rows very fine teeth. Labral sclerite extended dorsally, bending sharply medially at each end. Maxillary and labial palpi each slightly bulbous, with two sensoria. Antenna a little more than two times as long as width at base. Atrium of spiracle (Fig. 19) long, narrow, with about five reticulations; opening into long stalk with nine or 10 annulations and closing apparatus. Skin densely covered with cone-shaped protuberances, occasional short setae.

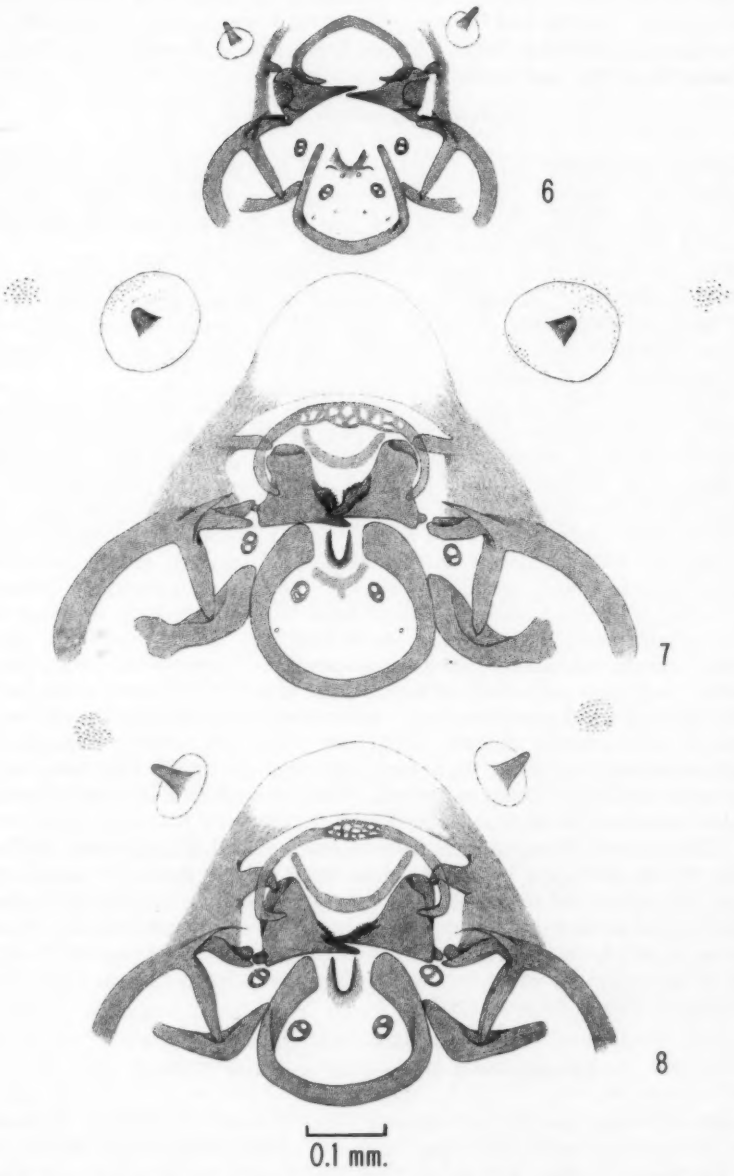
Endasys subclavatus (Say)

Endasys subclavatus (Say) was recorded as a parasite of *D. hercyniae* by Peirson and Nash (1940) (as *Stylocryptus vulgaris* Cress.), Reeks (1938), and Townes and Townes (1951), and was described and illustrated by Finlayson (1960) and Short (1959).

Cryptinae: Aptesini

Aptesis basizona (Grav.)

Aptesis basizona (Grav.) was recorded as a parasite of *D. hercyniae* by Reeks (1953), Townes and Townes (1951), and was reared in Belleville, Ont. from cocoons collected at Parke Reserve, Que. It was described and illustrated by Finlayson (1960) and Morris, Cameron, and Jepson (1937).



Figs. 6-8. Cephalic structures of final-instar hymenopterous larvae: 6, *Gelis urbanus* Brues; 7, *Aptesis subguttatus* (Grav.); 8, *Agrothereutes abbreviator similaris* Prov.

Aptesis indistincta (Prov.)

Aptesis indistincta (Prov.) was recorded as a parasite of *D. hercyniae* by Reeks (1938), Townes and Townes (1951), and was reared in Belleville, Ont. from cocoons collected at Parke Reserve, Que. It was described and illustrated by Finlayson (1960) and Short (1959).

Aptesis subguttatus (Grav.)

Figs. 7, 20

Aptesis subguttatus (Grav.) was recorded as a parasite of *D. hercyniae* by Finlayson and Finlayson (1958a). It is a parasite of *D. similis* (Htg.) and *Neodiprion sertifer* (Geoff.) in Europe and was liberated in Canada in attempts to control *D. hercyniae* (Finlayson and Finlayson, 1958a).

Exit hole round, fairly regular in outline, almost at tip of host cocoon, about 2.2 mm. in diameter. Parasite cocoon similar in size and shape to host cocoon; fairly thick, layered, shiny on inside, some fuzz on outside; whitish with brown fibres on outside to light brown in colour. Parasite remains are in meconium at end of parasite cocoon opposite exit hole.

Cephalic structure of last larval instar (Fig. 7) with complete epistoma, but appearing incomplete because dorsal portion unsclerotized. Each superior mandibular process long, heavy-set; inferior mandibular processes each consisting of two long struts. Lacinial sclerite long and conspicuous. Hypostomal spur long, slender, almost four times as long as width at base. Stipital sclerite meets labial sclerite at angle greater than right angle. Labial sclerite almost round in shape with slightly widened dorsal arms. Silk press U-shaped, heavily sclerotized. Prelabial sclerite usually present, sometimes difficult to distinguish. Mandible with heavily sclerotized blade swollen at bases of two rows long, irregular teeth. Labral sclerite rounded, extending about half way down mandibles, curving medially at each end, dorsally containing vacuoles. Suspensorial sclerite present. Maxillary and labial palpi each with two large sensoria. Antenna about as wide at base as long, small protuberances present around antennal socket and on skin lateral to each socket. Atrium of spiracle (Fig. 20) slightly tapered, with reticulations; slightly wider than long; opening into stalk with four or five annulations and large closing apparatus. Skin covered with minute cone-shaped spicules, occasional short setae.

This species is distinguishable from *A. basizona* and *A. indistincta* in that the stipital sclerite meets the labial ring at an angle greater than right angle, rather than at an angle equal to or less than right angle; and by the presence of small protuberances around each antennal socket. It is distinguished also from *A. basizona* in not having the dorsal arms of the labial ring greatly widened; and from *A. indistincta* in having vacuoles in the labral sclerite, and the blade of each mandible swollen at bases of teeth.

Cryptinae: Cryptini

Agrothereutes abbreviator similaris (Prov.)

Figs. 8, 21

Agrothereutes abbreviator similaris (Prov.) was recorded, as *A. slossonae* Cush., as a parasite of *D. hercyniae* by Reeks (1938), Peirson and Nash (1940), and Thompson (1944), and as *A. similaris* (Prov.), by Townes and Townes (1951), and was reared at Belleville, Ont. from cocoons collected at Parke Reserve, Que. in 1940; and of *Heterarthrus nemoratus* (Fall.) by Townes and Townes.

Exit hole to side of tip, round, irregular, about 1.9 mm. in diameter. Parasite cocoon similar in size and shape to host cocoon; thick, layered, fuzzy on out-

side, hard, shiny layer on inside; colour white to rusty-brown on outside, white inside. Parasite remains are in meconium at end of parasite cocoon opposite exit hole.

Cephalic structure of last larval instar (Fig. 8) with complete epistoma, but appearing incomplete because unsclerotized dorsally. Superior mandibular processes each heavy-based, curved, with evidence of indentation some distance below base; each inferior mandibular process consisting of two long struts, the posterior one larger than anterior. Lacinial sclerites present. Hypostomal arm short, curving latero-ventrally. Hypostomal spur about five times as long as width at base. Stipital sclerite turns upward at labial sclerite. Labial sclerite widely U-shaped, lateral arms broadened dorsally. Silk press sclerotized. Prelabial sclerite not evident in specimens examined; two triangular sclerotized areas sometimes evident below prelabial sclerite. Mandible with blade having two rows large uneven teeth on proximal half. Labral sclerite widely arched with small vacuoles dorsally, extending about half-way down mandibles, turning medially at each end at almost a right angle. Long suspensorial sclerite present, curving forward under labral sclerite and mandibles. Fine teeth apparent on roof of hypopharynx. Maxillary and labial palpi each with two unequal-sized sensoria. Antenna cone-shaped, twice as long as width at base. Area with small rounded protuberances lateral to each antenna. Atrium of spiracle (Fig. 21) with reticulations, almost same width as length; opening into stalk with three or four annulations, strong closing apparatus. Skin covered with cone-shaped papillae, a few setae.

Mesoleiinae: Mesoleiini

***Mesoleius tenthredinis* Morl.**

Figs. 9, 22

Mesoleius tenthredinis Morl. was recorded as a parasite of *D. hercyniae* by Townes and Townes (1951) and was reared in Belleville, Ont. from cocoons collected in Laurentide Park, Que. in 1943; and of *Pristiphora erichsonii* (Htg.) by Baird (1939), Bird (1939), Craighead (1950), Criddle (1928), Daviault (1944), de Gryse (1935), Dowden (1937), Graham (1931, 1953), Hawboldt (1942), Hewitt (1911, 1912), Hopping (1935), LeJeune (1947), Swaine (1928), and Townes and Townes. The cephalic structure of the last larval instar was described and illustrated by Beirne (1941), Graham (1953), and Short (1959).

Exit hole slightly off tip of host cocoon; irregular, jagged; about 2.8 mm. in diameter. Parasite cocoon similar in size and shape to host cocoon; beige-grey with a few darker fibres; thin, transparent, shiny, some fuzz on outside. Parasite remains are embedded in meconium at end of parasite cocoon opposite exit hole.

Cephalic structure of last larval instar (Fig. 9) with epistoma that may or may not be complete; if complete, dorsal part very fragile, easily broken, difficult to see. Pleurostomae each wide, diffuse. Inferior mandibular processes each with two slender struts. Lacinial sclerite inconspicuous but present. Hypostomal arm long, arched latero-ventrally. Hypostomal spur short, extending to large stipital sclerite which overlaps top of dorsal arm of labial sclerite. Labial sclerite complete ventrally with dorsal projection from ventral part; each dorsal arm heavily sclerotized, widened medially, with prominent lateral projection. Short (1959) stated that he did not see these projections, but they are present in the specimens examined in the present study. Silk press long, narrow, lightly sclerotized; Y-shaped prelabial sclerite slightly visible in some specimens. Labral sclerite absent. Blade of mandible without teeth, meeting body of mandible at an angle slightly greater than right angle. Maxillary and labial palpi

each with one large, one or more small sensoria. Antennae inconspicuous. Skin densely covered with minute rounded protuberances. Atrium of spiracle (Fig. 22) very small, oval, opening into wider stalk with one or two annulations and a long, thin-walled closing apparatus.

***Mesoleius* sp. (possibly *viduus* Hgn.)**

Figs. 10, 23

Mesoleius sp. possibly *viduus* Hgn. was recorded from *D. hercyniae* in Quebec by Reeks (1938), and two of his specimens were examined in the present study.

Exit hole well to side of tip of host cocoon, irregular in outline, about 1.4 mm. in diameter. Parasite cocoon similar in size and shape to host cocoon; greyish-white in colour; thin, slightly fuzzy. Parasite remains are in meconium, along side of cocoon in specimens examined.

Cephalic structure of last larval instar (Fig. 10) similar to *M. tenthredinis* except that stipital sclerite has dorsal projection at lateral end; each dorsal arm of labial sclerite without prominent lateral projection and with medial part serrated and curving to meet ventral part of arm whereas there is sharp angle in *M. tenthredinis;* mandible longer and narrower with protuberance on dorsal surface, wide blade meets body of mandible at angle much greater than right angle. Spiracle (Fig. 23) very similar to that of *M. tenthredinis.*

***Lamachus* sp.**

One specimen of *Lamachus* sp. was reared from cocoons of *D. hercyniae* collected in Matapedia County, Que. in 1936. It is not the same species as that described and illustrated by Finlayson (1960) from *N. sertifer,* but the cephalic structure of the last larval instar is similar.

Chalcidoidea: Eulophidae
Eulophinae
***Dahlbominus fuscipennis* (Zett.)**

Dahlbominus fuscipennis (Zett.) was recorded as a parasite of *D. hercyniae* by Baird (1939), Dowden (1939), Peck (1951), Reeks (1952, 1953), and was reared at Belleville, Ont. from cocoons collected in Quebec. It was described and illustrated by Finlayson (1960) (as *D. fuliginosus* Nees) and Morris and Cameron (1935).

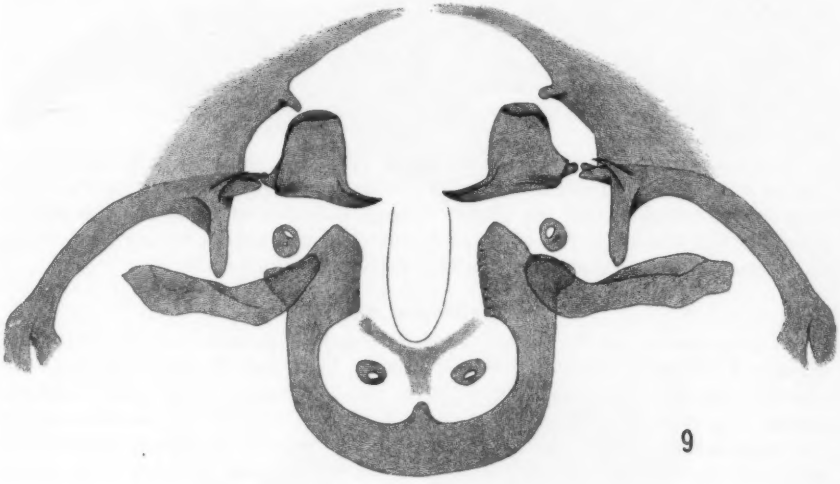
Torymidae: Monodontomerinae
***Monodontomerus dentipes* (Dalm.)**

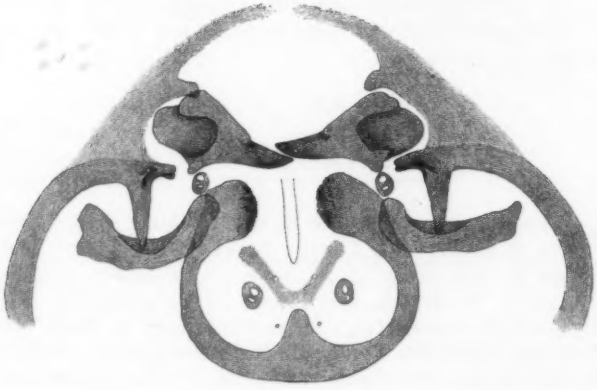
Monodontomerus dentipes (Dalm.) was recorded as a parasite of *D. hercyniae* by Peck (1951) and was described and illustrated by Finlayson (1960).

Pteromalidae
Pteromalinae: Pteromalini
***Amblymerus verditer* (Nort.)**

Figs. 11, 24

Amblymerus verditer (Nort.) was recorded as a parasite of *D. hercyniae* by Martineau (1959) and Peck (1951), and two additional instances of parasitism were obtained through correspondence with Dr. B. M. McGugan, Research Branch, Ottawa; of *D. similis* in the United States by Thompson (1944); of *N. abietis* by Peck and by Raizenne (1957); of *N. pratti banksianae* by Griffiths (1960); of *N. lecontei* (Fitch) by Benjamin (1955); of *N. tsugae* Midd. by Furniss and Dowden (1941) and Peck; and of various other hosts, including the





Figs. 9-11. Cephalic structures of final-instar hymenopterous larvae: 9, *Mesoleius tenthredinis* Morl.; 10, *Mesoleius* sp. (possibly *viduus* Hgn.); 11, *Amblymerus verditer* (Nort.).

Lepidpoptera *Choristoneura fumiferana* (Clem.) and *Archippus packardianus* Fern., by Peck. Dowden, Buchanan, and Carolin (1948) listed it as a secondary parasite of two pupal parasites of the spruce budworm, *C. fumiferana*, but there was no evidence of this in the specimens examined.

Exit hole or holes small, round, regular, on side of host cocoon near end; about 0.8 mm. in diameter. Host cocoon containing remains of sawfly larva; numerous straw-coloured cast pupal skins; small, thread-like, whitish cast skins of last larval instar.

Cephalic structure of last larval instar (Fig. 11) showing only mandibles. Can be separated from *Dibrachys cavus* (Wlkr.) and *D. fuscipennis* by the large cone-shaped antennae that are almost as large as blades of mandibles but not so pointed. Spiracle (Fig. 24) with large, funnel-shaped atrium having eight to 10 chambers; small closing apparatus. Skin with a few short setae.

Tritneptis spp.

Three species of *Tritneptis* were recorded as parasites of *D. hercyniae*, namely: *T. diprionis* Gahan, *T. hemerocampae* Grlt., and *T. klugii* (Ratz.). *T. diprionis* was recorded by Raizenne (1957) and *T. klugii* by Peck (1951) and the former was described and illustrated by Finlayson (1960). *T. hemerocampae* was recorded as a parasite of *D. hercyniae* by Peck (1951) and Reeks (1938); and there are several unpublished instances of rearing it from cocoons collected in Quebec in 1932 (B. M. McGugan, *in litt.*).

Dibrachys cavus (Wlkr.)

Dibrachys cavus (Wlkr.) was recorded as a parasite of *D. hercyniae* by Peck (1951) and was described and illustrated by Finlayson (1960) and described by Morris, Cameron, and Jepson (1937).

Diptera

Tachinidae

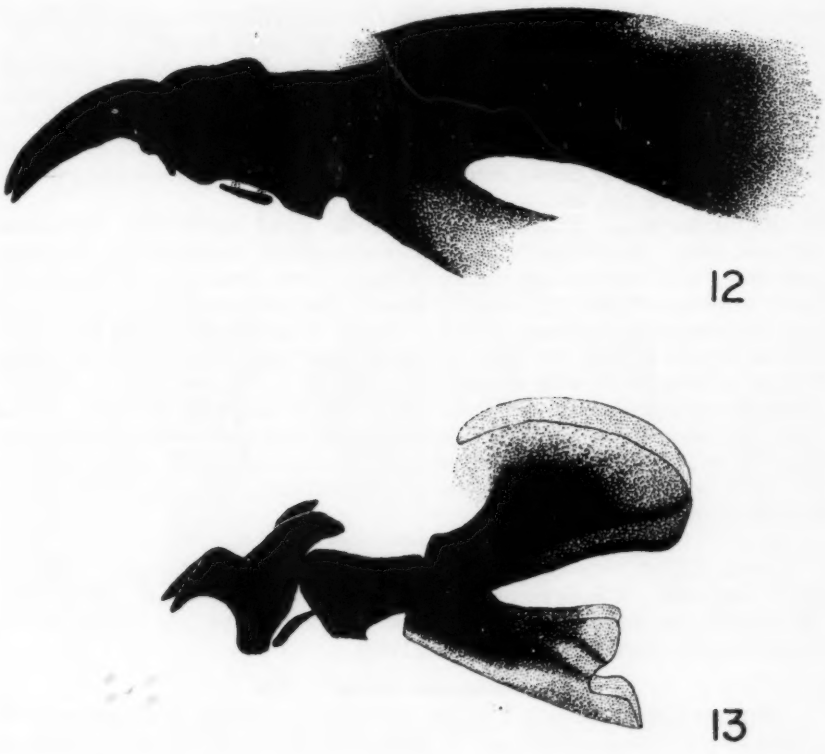
Bessa harveyi (Tns.)

Fig. 12

Bessa harveyi (Tns.) was recorded (as *B. selecta* (Meig.)) as a parasite of *D. hercyniae* in New Brunswick and Quebec by Hawboldt (1947) and Reeks (1938); of *N. abietis* by Hawboldt; of *P. erichsonii* by Baird (1922), Britton (1915), Dowden (1937), Hawboldt, and Reeks; of *P. geniculata* (Htg.) by Hawboldt; of *Pikonema alaskensis* (Roh.) by Hawboldt and by Nash (1939); of *P. dimmockii* (Cress.) by Hawboldt and by Reeks; of *Hemichroa crocea* (Fourc.) by Hopping (1937); and of a few lepidopterous hosts. The species is thought to be of European origin and the biology was discussed and the immature stages were described and illustrated by Hawboldt.

Exit hole almost at tip of host cocoon, edge with slight "pushed-out" appearance, about 1.4 mm. in diameter. Mature larva emerges from host cocoon to form puparium leaving remains of host in a crumpled heap at one end of cocoon. Hawboldt (1947) stated that the puparium is sometimes formed within the host cocoon, but this condition was not encountered in any of the present specimens examined. Remains of penultimate larval instar within remains of host larva.

Buccopharyngeal armature of penultimate larval instar (Fig. 12) heavily sclerotized, about 0.618 mm. long by 0.19 mm. wide at widest point. Mandibular hooks each long, slender, curving slightly antero-ventrally. No visible articulation between hooks and intermediate sclerite, or intermediate sclerite and basal sclerite. Basal sclerite with two long, narrow, dorsal wings, two short, ventral



Figs. 12-13. Lateral views of buccopharyngeal apparatus of penultimate-instar dipterous larvae: 12, *Bessa harveyi* (Meig.); 13, *Drino* (*Prosturmia*) *bohemica* Mesn.

wings. Slight anterior dorsal projection on margin of dorsal wings. Salivary gland plate visible ventral to intermediate sclerite. Skin with many rows conspicuous spines.

***Diplostichus hamatus* (A. and W.)**

Diplostichus hamatus (A. and W.) was recorded as a parasite of *D. hercyniae* by Raizenne (1957) and Reeks (1938); and it was reared in Belleville from cocoons collected in Quebec. It was described and illustrated by Finlayson (1960).

***Drino* (*Prosturmia*) *bohemica* Mesn.**

Fig. 13

Drino (*Prosturmia*) *bohemica* Mesn. is a Scandinavian parasite that was liberated in Canada in attempts to control the European spruce sawfly, *D. hercyniae* (Finlayson and Finlayson, 1958a, 1958b). It was recorded as a parasite of *D. hercyniae* in Ontario by Raizenne (1957), and in New Brunswick by

Reeks (1953), and was reared in Belleville, Ont. from cocoons collected at Parke Reserve, Que.; and of *P. alaskensis* and *P. dimmockii* by Reeks.

Exit hole on tip of host cocoon, round, regular, slight "pushed-out" appearance, about 1.3 mm. in diameter; slight ridge surrounding hole within cocoon. Mature larva emerges from host cocoon to form puparium leaving skin of host larva round and completely hollowed out. In specimens examined, remains of next to last larval instar found inside skin of host larva at its caudal end which is at exit end of host cocoon.

Buccopharyngeal armature of penultimate larval instar (Fig. 13) about 0.45 mm. long. Mandibular hooks heavily sclerotized, curving antero-ventrally, articulating with intermediate region. Distance from anterior tip of mandibular hooks to postero-dorsal angle slightly greater than distance from postero-dorsal angle to ventral projection of hooks. Length of mandibular hooks plus intermediate region slightly less than length of basal region. Intermediate region heavily sclerotized, showing constriction at junction with basal region. Hypopharyngeal sclerite present at anterior ventral end of intermediate region. Basal region divides into two fan-shaped dorsal wings and two narrower ventral wings. Slight anterior dorsal projection on margin of dorsal wings. Skin of larva possessing several rows conspicuous spines anteriorly, less conspicuous spines toward posterior.

***Neophorocera edwardsii* (Will.)**

Reeks (1938) recorded *Phorocera* sp. near *claripennis* (Macq.) as a parasite of *D. hercyniae*. This is presumed to be *Neophorocera edwardsii* (Will.), but the original specimens were not available for examination. *N. edwardsii* was described and illustrated by Finlayson (1960).

***Spathimeigenia spinigera* Tns.**

Spathimeigenia spinigera Tns. was recorded as a parasite of *D. hercyniae* in Ontario by Raizenne (1957) and in Quebec by Reeks (1938) (as *S. aurifrons* Curr.). Mr. J. F. McAlpine, Entomology Research Institute, Ottawa, Ont. stated *in litt.*: "the present state of our knowledge concerning them [*S. spinigera* and *S. aurifrons*] is such that we do not know whether we are dealing with a single variable species or a complex of several sibling species. The group is in great need of an exhaustive study, and until we know more about its taxonomy, the application of specific names to certain specimens is meaningless. Under these circumstances I feel it is better to refer all specimens to the 'Spathimeigenia spinigera complex'." Examination of the buccopharyngeal armature of the last instar larva of the specimens of *S. aurifrons* reared by Reeks revealed them to be similar in all respects to *S. spinigera* as described and illustrated by Finlayson (1960).

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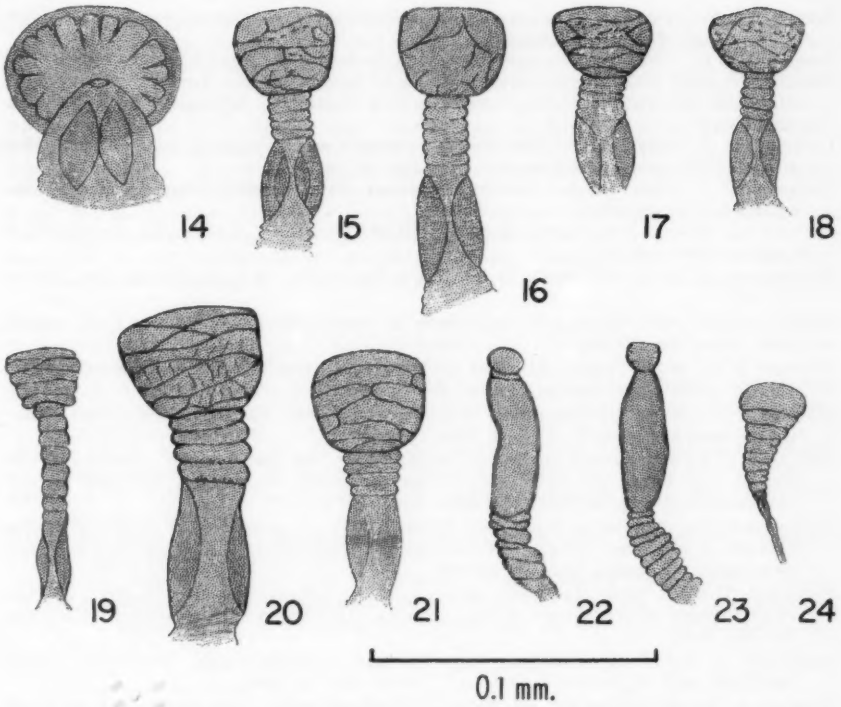
The writer wishes to thank the following for identification of adult parasites: Mr. J. F. McAlpine, Dr. W. R. M. Mason, Dr. O. Peck, and Mr. G. S. Walley of the Entomology Research Institute, Canada Department of Agriculture, Ottawa, Ont.; and Dr. H. K. Townes, Museum of Zoology, University of Michigan, Ann Arbor, Michigan. Grateful acknowledgment is made to Dr. B. M. McGugan, Forest Biology Division, Canada Department of Agriculture, Ottawa, Ont., for obtaining extensive records of parasites reared from *D. hercyniae* by the staff of the Forest Biology Division.

SUMMARY

Twenty-eight species of parasites of *Diprion hercyniae* (Htg.) are separated by using characters of the parasite remains in the host cocoons from which the



Figs. 14-24. Spiracles of final-instar hymenopterous larvae: 14, *Pimpla pedalis* Cress.; 15, *Exenterus confusus* Kerr.; 16, *E. affinis* Roh.; 17, *E. tricolor* Rom.; 18, *E. vellicatus* Cush.; 19, *Gelis urbanus* Brues; 20, *Aptesis subguttatus* (Grav.); 21, *Agrothereutes abbreviator similaris* Prov.; 22, *Mesoleius tenthredinis* Morl.; 23, *Mesoleius* sp. (possibly *viduus* Hgn.); 24, *Amblymerus verditer* (Nort.).

parasites emerged. Thirteen species are described and illustrated here and the remaining 15 species were described and illustrated by Finlayson (1960).

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A Study of the Flight of the Douglas-Fir Beetle *Dendroctonus pseudotsugae* Hopk. (Coleoptera: Scolytidae) II. Flight Movements[1]

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The concern caused by extensive killing of marketable Douglas-fir *Pseudotsuga menziesii* (Mirb.) Franco, in the interior of British Columbia by the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., has necessitated studies on many phases of the beetles' biology and behaviour. Among these has been a study of the beetles' flight. Although this insect flies for only a few brief periods during its life, these periods are vital in terms of the extension and location of areas of infestation.

In this paper I shall consider the flight movements of this important insect, the second phase of insect flight as outlined by Atkins (1959).

The studies were conducted in the vicinity of Vernon, Lac la Hache, and Victoria, B.C., from 1957 to 1959.

[1]Contribution No. 634, Forest Biology Division, Research Branch, Department of Agriculture, Ottawa, Canada. Based on studies for a thesis submitted to the Faculty of Graduate Studies of the University of British Columbia in partial fulfilment of the requirements for a degree of Master of Arts.

The Flight Movements

Flight movements are important since it is these actions that propel the insect through the air and control the direction and magnitude of dissemination. A beetle may take flight when the basic requirements for flight are sub- or supra-optimal due to stimulation by a secondary factor, but it is important to know whether or not and how successfully flight can continue under various conditions. If, for example, an insect is stimulated by exposure to sunlight to fly on a cool day would flight continue once the insect entered a shaded area in the forest? Questions such as this are particularly applicable to spring flying insects like the Douglas-fir beetle, because of the frequency with which the basic conditions of flight are outside the limits of the activity. Adaptation to various conditions prior to activity may also be significant (Gunn & Hopf, 1942), but it will not be considered here. The experiments conducted concern only the flight movements themselves and how they are affected by changes in the beetles' environment. Aerodynamics is not within the scope of this paper since it is a study apart from behaviour.

The main movements to be considered in this section are the wing beat frequency, amplitude of the beat of the wings and elytra, and the deflection of the wings.

The Normal Wing-beat Amplitude and Deflection

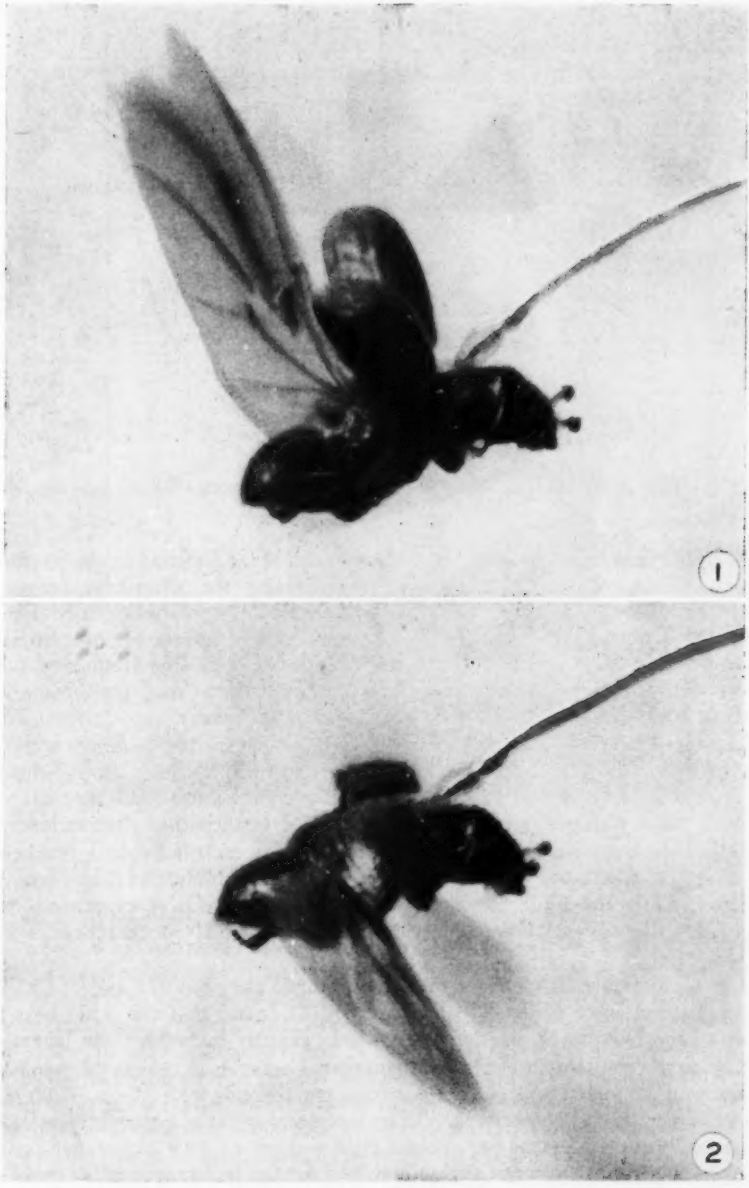
The wing-beat amplitude and wing deflection were studied with the aid of photography and the stroboscope, while the beetles flew on either a fixed mount or a balance.

Observed from a point at right angles to the stroke plane, the amplitude of wing-beat of various insects varies from 70° in *Aeshna* (Odonata) to 160° and 180° in *Lucanus cervus* and *Priacma serrata* (Coleoptera) respectively (Magnan, 1934 and Atkins, 1958), while Pringle (1957) noted the possibility of it being greater than 180° in some beetles. In the Douglas-fir beetle the wing-tips initially described arcs of 187 degrees, while the broader anal portions travelled farther due to wing deflection. At the top of the stroke the wings came together for their full length, although the broader portions touched only slightly after the tips as the wings underwent a pronation twist. At the bottom of the stroke the wings stopped at the vertical, with the exception of the broader portions, which touched as the wings rotated on their long axis. The tip of each elytron described an arc of 40° to 45° upwards from the horizontal, a movement considerably more than is reported for beetles by Pringle (1950, 1957) (Figs. 1 and 2). The amplitudes pictured in Fig. 3 are considered normal for *D. pseudotsugae* although variations do occur.

By adjusting the stroboscope so that the flashing tube was one or two cycles out of phase with the wing-beat, the secondary wing movements could easily be observed. On a fixed mount with a gentle flow of air directed from in front of the beetle, the wing tip curve was similar to that reported for many other insects, moving forward and downward with a positive angle of attack and returning backward and upward.

The Effect of Associates on the Wing-beat Frequency and Amplitude

Young adult beetles which emerged from their brood logs at various times of the year were collected and subjected to flight stimulation by tossing. Those showing a strong positive response were used in the following tests. Four samples of 100 spring-emerged beetles, two from each of two years, and one sample of 100 summer-emerged beetles were used.



Figs. 1, 2. Douglas-fir beetle flying on a fixed mount showing amplitude of elytra; elevated above, depressed below.

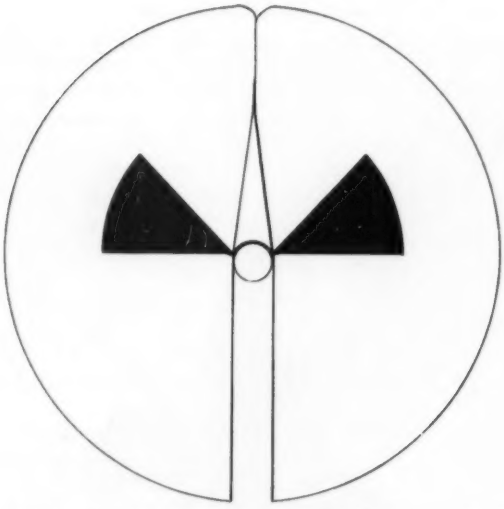


Fig. 3. The wing-beat amplitude of the Douglas-fir beetle. Black indicates elytral amplitude.

Each beetle was mounted on an aluminum-foil point fastened to the prothorax by wax. The stroboscope method of determining the wing-beat frequency (Chadwick, 1939a) was used. The calibration of the stroboscope used for the two initial samples was checked by an oscilloscope screen against an audio generator, which was checked at the 60-cycle point with line frequency. The over-all accuracy was estimated at $\pm$ 5 per cent. All later tests were made with a Nichols Probostrobe with an accuracy of $\pm$ 1 per cent.

In all experiments involving the wing-beat frequency the readings were not taken until the insect had been flying for some seconds, because during the first few seconds the rate of beat reaches a value above the steady level later adopted. However, these changes occurred too rapidly for quantitative observations.

Following the wing-beat frequency readings for each individual, the beetles were dissected, sexed, and examined for the presence or absence of nemic and mite associates. Only the adult nematodes were counted. Relative expressions were used to describe the number of larval forms due to their occurrence in large numbers.

The temperature throughout these tests ranged between 73° and 75° F., and was disregarded since Rudinsky and Vité (1956) found that the wing-beat frequency of the Douglas-fir beetle changed only slightly between these levels.

The first two samples of spring-emerged beetles had ranges of wing-beat frequency of 78 to 100 and 76 to 105 cycles per second, with means of 90.2 and 89.4 cycles per second respectively. The sample of summer emerged beetles had a range of 78 to 105 cycles per second with a mean of 89.9 cycles per second. The remaining two samples of spring emerged beetles had ranges of 60 to 97 and 73 to 97 cycles per second, with means of 87.4 and 88.0 cycles per second respectively.

Student's "t" test was used to analyse the data. No significant difference was found between uninfested males and females in any of the samples, so the total number of uninfested beetles in each sample was used as a basis for com-

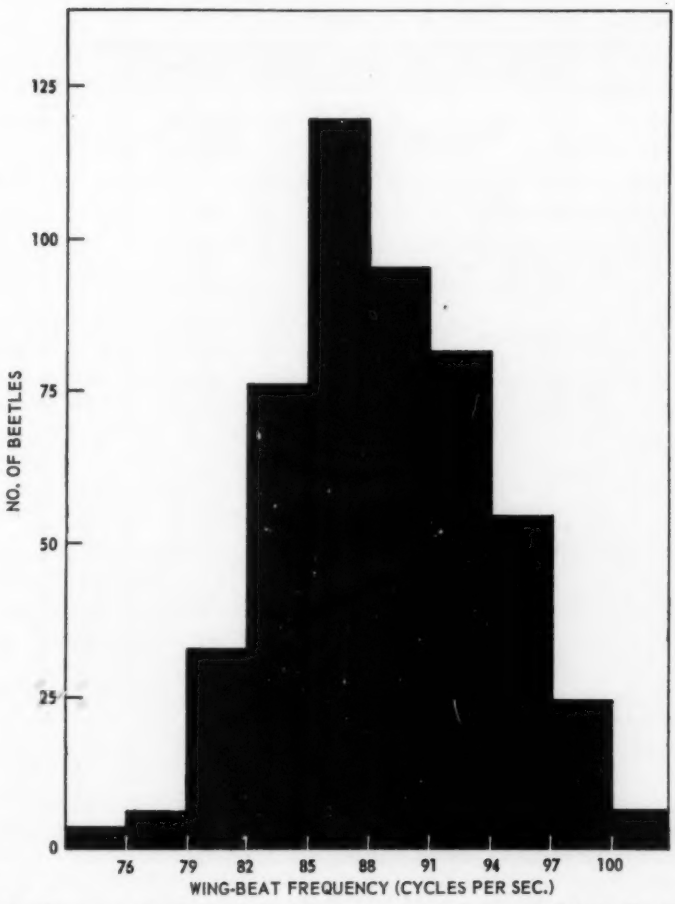


Fig. 4. Frequency distribution of wing-beat frequencies of 500 Douglas-fir beetles.

parison with the infested groups of the corresponding sample. Preliminary analysis showed that mites had no effect on the wing-beat frequency, except in a special case described later, so they were eliminated from the final analysis. In each sample the uninfested beetles were compared with those infested with internal nematodes, external nematodes, and both internal and external nematodes. The means, degrees of freedom, and "t" values are presented in Table I.

In the first sample, the significant differences between the uninfested beetles and those infested by internal nematodes alone is not considered solely due to the nematodes. If these had an effect by themselves they also should have shown an effect in the group infested by both internal and external nematodes.

A histogram of frequency distribution of the wing-beat frequencies of 500 Douglas-fir beetles taken between 73° and 75° F., and 45 per cent relative humidity is shown in Fig. 4.

The exceptional case in which mites affected the wing-beat frequency occurred when they formed a cluster on the tips of the elytra. The mean wing-beat frequency of 11 beetles infested with mites in this manner was 84 cycles per

TABLE I

Analysis of the wing-beat frequency of 5 samples of 100 Douglas-fir beetles with various degrees of nematode infestation

Sample	Comparison	Mean frequency in cycles/sec.	d.f.	"t"
1	Uninfested with:	88.9		
	(A) External nematodes only	90.4	70	1.1737
	(B) Internal nematodes only	93.7	45	3.3426**
	(C) Internal & external nematodes	90.7	51	.9419
2	Uninfested with:	89.2		
	(A) External nematodes only	88.5	72	.4711
	(B) Internal nematodes only	91.8	45	1.614
	(C) Internal & external nematodes	89.8	43	.3768
3	Uninfested with:	90.6		
	(A) External nematodes only	91.1	71	.1509
	(B) Internal nematodes only	91.0	40	.1227
	(C) Internal & external nematodes	89.9	49	.2113
4	Uninfested with:	87.4		
	(A) External nematodes only	87.2	67	.1512
	(B) Internal nematodes only	87.8	47	.2841
	(C) Internal & external nematodes	88.5	54	.3928
5	Uninfested with:	88.4		
	(A) External nematodes only	87.9	81	.3049
	(B) Internal nematodes only	87.2	24	.4954
	(C) Internal & external nematodes	86.8	31	.3871

** Significantly different at the 1 per cent level.

second compared with a mean of 89.3 cycles per second for the remaining 489 beetles. The mites probably acted as a loading mechanism reducing the wing-beat frequency through their weight on the elytra.

Throughout the last two samples of beetles, observations were made to determine whether or not the associates caused any reduction in wing-beat amplitude which might result in changes in the wing-beat frequency. The amplitude described earlier was considered normal and reductions were estimated in degrees at both top and bottom of the stroke. However, there was no correlation between reduced amplitude and differences in wing-beat frequency. The mean frequency for 37 beetles with reduced amplitude was 86.2 cycles per second compared with 86.3 cycles per second for the remaining 163 with normal amplitude. Furthermore, there was no definite correlation between infested beetles and reduced amplitude, although the incidence of amplitude reduction was higher in the group of beetles infested by internal nematodes.

It is interesting that the internal nematodes appeared to have no effect on the beetles' flight movements even though some of the species that were present, *Aphelenchulus* spp., *Aphelenchoides* sp., and *Sphaerularia* spp., are known to be true parasites (Van Zwaluwenberg, 1928; Massey, 1956). If the significant

TABLE II

Results of wing-beat frequency readings for five samples of Douglas-fir beetles at different temperatures

Sample	Temperature (°F.)	Mean	Range
1	70	92.8	82 - 105
2	76	94.0	87 - 102.5
3	80	94.9	81 - 102
4	84	95.8	86 - 103
5	90	96.6	88 - 102

difference noted in the first sample was actually due to the nematodes and not to sampling as is suspected, it is interesting to note in view of the work of Fuchs (1920) and Reid (1955) that the wing-beat frequency was increased rather than decreased. Weis-Fogh (1956) noted that mermithids reduced or impeded the flight of locusts, while Moeller (1956) noted that bees were stimulated to fly by the presence of nosema parasites. It is possible that some internal nematodes would increase the wing-beat frequency by excitation, but difficulties in nematode identification prevent analysis of the data by nemic species.

The Effect of Temperature on Wing-beat Frequency and Amplitude

Initially, 5 samples of 50 flight-positive spring-emerged beetles were tested. Each individual was mounted on an aluminum foil point and stimulated to fly near the flashing tube of the Nichols Probostrobe in order to observe the wing-beat frequency and amplitude at the prevailing temperature. This procedure was followed with one of the samples at one of the following temperatures: 70°, 76°, 80°, 84° and 90° F. The resulting ranges and means are presented in Table II. Although the means showed a definite increase with temperature, the ranges did not, due to natural variation between the samples.

In order to control the variation between the samples, six groups of 20 beetles were taken from the same source as those in the preceding experiment and each group was studied throughout a temperature range. Following the wing-beat frequency and amplitude observations at one temperature, the beetles were put to rest until the temperature changed a few degrees, at which time another set of observations was made. This was repeated until each sample had been observed at four different temperatures. Three of the samples were studied with increasing and three with decreasing temperature. With this method, both the ranges and means increased with temperature. The results are presented in Table III. Additional observations indicated that at temperatures above 100° F. (38° C.), the wing-beat frequency of the beetles dropped as the thermal death point (120° F. or 49° C.) was approached and heat prostration occurred. The results of these studies are shown in Fig. 5.

Temperature did not affect the wing-beat amplitude. In cases where the amplitude changed there was no relation to temperature but rather to the duration of flight activity. This was evident mostly in the last observations. These changes were probably due to fatigue (see later section).

It seems noteworthy that the wing-beat frequency increased rapidly with temperature to 68° to 72° F., the point at which spontaneous flight occurs. Once the optimal temperature for flight was reached the wing-beat frequency increased by only a few cycles per second with an additional rise of 18° F. in temperature.

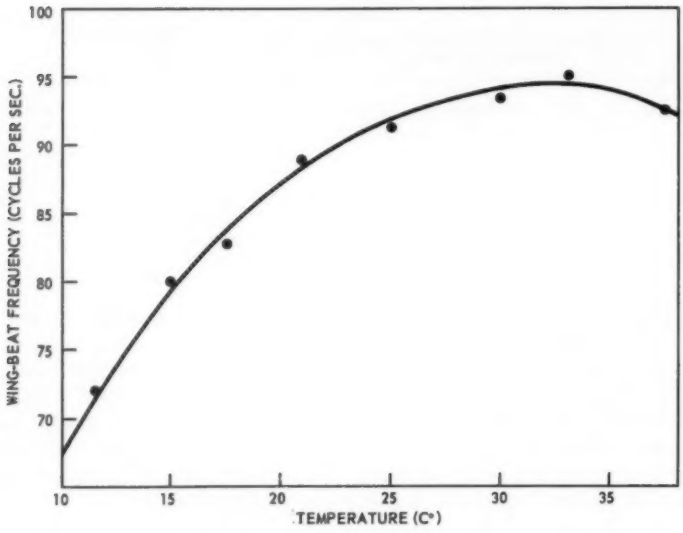


Fig. 5. The relationship between the wing-beat frequency of the Douglas-fir beetle and temperature.

The Effect of Relative Humidity on Wing-beat Frequency and Amplitude

The wing-beat frequencies and amplitudes of a number of beetles mounted on aluminum-foil points were observed with the aid of the Nichols Probostrobe. The observations were made at various relative humidities (RH) ranging from 25 to 98 per cent at 67° F., 18 to 96 per cent at 75° F., and 25 to 96 per cent at 85° F. At least one sample of 20 beetles was used at each temperature and humidity. The resulting mean of each sample was used in the graphical presentation in Fig. 6.

The increase in wing-beat frequency resulting from an increase in RH., was probably due to changes in the insects' ability to cool themselves by evaporation of body water, since the temperature of insects indoors does not generally differ greatly from that of the environment, although it is definitely lower in dry air and higher in moist air (Krogh and Zeuthen, 1940). The decrease in wing-beat frequency evident at higher RH., was probably due to heat prostration resulting from the inability to cool. This observation is further exemplified by the fact that the wing-beat frequency decreased at a lower RH when the air temperature was highest.

At temperatures below the optimum for flight the higher RH appeared to increase wing-beat frequency significantly and may be important during the spring flight period when temperatures are generally lower and humidities higher. At 75° F., which is very suitable for Douglas-fir beetle flight, there is little change in the wing-beat frequency over the more common range of relative humidity.

The relative humidity did not generally affect the wing-beat amplitude, although a number of beetles observed at 96 and 98 per cent RH showed a slight reduction in amplitude at the top of the beat. This may have been due to the increased density of the air.

TABLE III

Results of wing-beat frequency readings for six samples of Douglas-fir beetles with varying temperatures

Sample	Temperature (°F.)	Mean frequency in cycles/sec.	Frequency range in cycles/sec.
1*	64	79.7	72 - 87
	72	88.9	78 - 97
	75	89.1	80 - 98
	79	91.4	80 - 102
2	68	92.1	88 - 97
	75	94.9	88 - 100
	78	96.2	87 - 102
	88	96.6	88 - 103
3	65	86.7	79 - 93
	76	95.7	89 - 103
	80	96.9	92 - 103
	90	97.1	92 - 105
4*	72	95.5	88 - 103
	76	97.3	90 - 104
	80	97.9	90 - 105
	86	98.1	91 - 105
5	76	94.8	87 - 100
	80	95.8	87 - 102
	85	96.2	88 - 100
	90	96.4	88 - 100
6*	64	86.8	83 - 95
	76	92.8	87 - 100
	80	94.5	87 - 102
	86	94.9	88 - 102

* Sample studied under decreasing temperature.

The Effect of Light Intensity on Wing-beat Frequency and Amplitude

Young adults which emerged during the winter from spring-attacked logs brought into the laboratory were used. Six samples of 10 beetles that showed a strong flight inclination were tested at each of the following light intensities: 15, 60, 100, and 300 foot candles. Three samples were observed with increasing, and three with decreasing light intensity, thus reducing any error due to fatigue. The beetles were allowed 10 minutes for adaptation at each light intensity prior to the wing-beat frequency readings, since the rate of activity under one light intensity may carry over during the early stages of subjection to another intensity (Digby, 1957). The light intensity was controlled with incandescent lamps separated from the experimental area by a water bath to prevent large changes in temperature. The lowest light intensity used was considerably higher than that at which flight will occur (Atkins, 1959), but constituted the light produced by the flashing tube of the stroboscope. The results are presented graphically in Fig. 7. The value shown for five foot candles was estimated from indications obtained by filtering down the intensity of the strobe-light, although the frequency reading was not satisfactory.

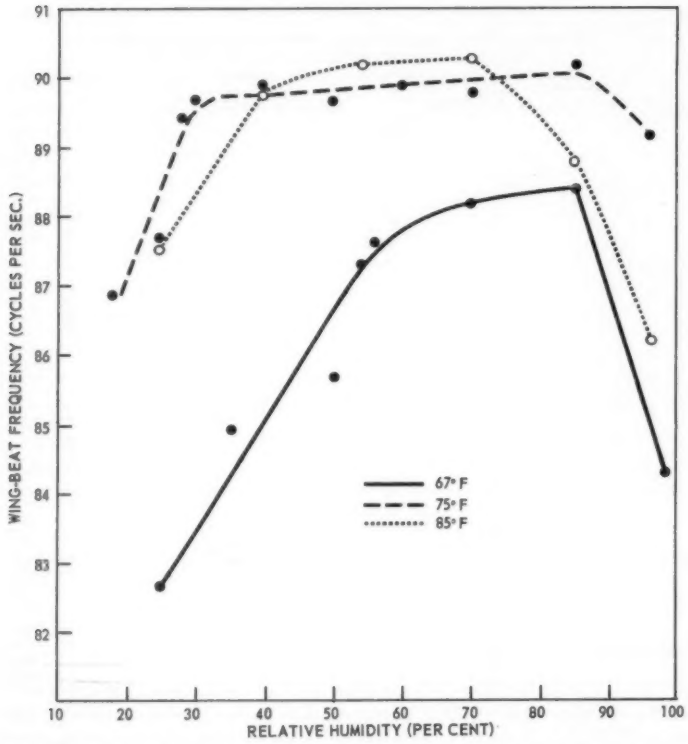


Fig. 6. The relationship between the wing-beat frequency of the Douglas-fir beetle and relative humidity.

The changes in wing-beat frequency that occurred with changes in light intensity were of low magnitude compared with those resulting from changes in temperature and humidity. They are probably due to differences in the intensity of the stimulus entering the insects' eyes. Such stimulation has been demonstrated in eye-patching experiments where light entering only one eye stimulates the muscles on the opposite side of the body to greater activity, producing a turn towards the light (Chen and Young, 1943; Popam, 1952).

The Effect of Reduced Atmospheric Pressure, Wing-clipping and Wing-loading on Wing-beat Frequency and Amplitude

The effects of reduced atmospheric pressure and wing mutilation on the wing-beat frequency and amplitude of the Douglas-fir beetle, suggested by the work of Chadwick (1939b), were investigated briefly. As in *Drosophila* (Chadwick and Williams, 1949) and many other insects (Sotavalta, 1952), a reduction of the atmospheric pressure increased the wing-beat frequency of the Douglas-fir beetle. Several beetles mounted on aluminum foil points were held by pins in a cork used to seal an inverted vacuum-flask. The wing-beat frequencies were taken at 1010 millibars and 10, 15, 20 and 25 pounds vacuum at 72° F., and 50 per cent RH. The wing-beat frequencies showed a mean increase of 1.6 cycles per second for each five pounds increase in vacuum.

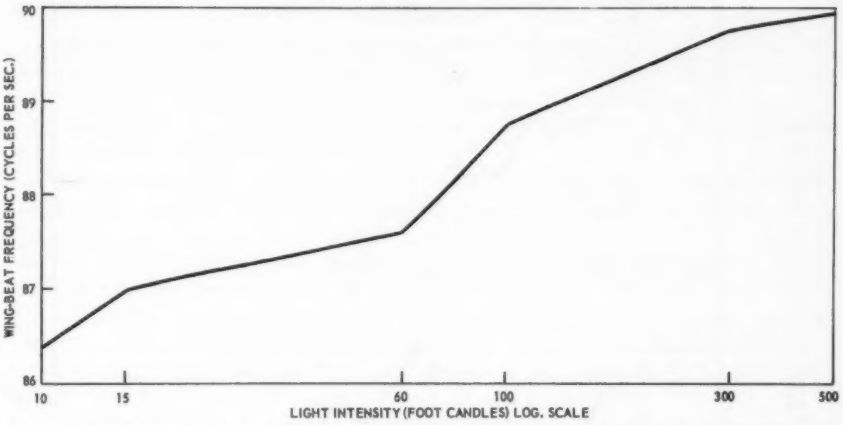


Fig. 7. The relationship between the wing-beat frequency of the Douglas-fir beetle and light intensity.

The clipping of one or both wings by approximately one-third was found to increase the beat frequency from one to six cycles per second, while small quantities of melted wax placed on the wing-tips decreased the beat frequency in tests conducted at the above temperature and RH.

The wing-beat amplitude was unchanged, except in the case of wing loading, when the amplitude was reduced by varying degrees that depended upon the amount of loading.

The increase in wing-beat frequency resulting from an increase in vacuum can be most easily explained by the reduced resistance offered to the wings. The fact that clipping one or both wings increased the beat frequency is contrary to the findings of Roch (1922) and Chadwick and Williams (1949), but in agreement with Sotavalta (1947, 1952). Sotavalta (1952) presents four theories to explain the increase in frequency resulting from wing clippings. (1) The frequency increases as a compensation for the reduced wing area within the requirements of a constant aerodynamic force to be produced. (2) The frequency increases because the air resistance offered the wings is less. (3) The frequency increases because the inertia of the oscillating system is reduced. (4) The frequency is altered due to a disturbance of the sensory balance. Sotavalta feels that the changes are due to reduction of the inertia. His findings may be supported by the fact that small quantities of melted wax placed on the wing-tips of the Douglas-fir beetle, which would tend to increase the inertia without altering the area, decreased the wing-beat frequency.

The Effect of Fatigue on Wing-beat Frequency and Amplitude

Twenty specimens of Douglas-fir beetle were mounted on aluminum-foil points and stimulated to fly. The light intensity was 30 foot candles, the temperature 73° F., and the relative humidity 45 per cent throughout the tests. The wing-beat frequency was measured and the amplitude observed every six minutes for four hours with the Nichols Probostrobe. Some representative results of changes in the wing-beat frequency are shown in Fig. 8. The average reduction in wing beat frequency for the 20 beetles tested after four hours flight was 17.95 per cent, this reduction being due almost certainly to fatigue. Working with

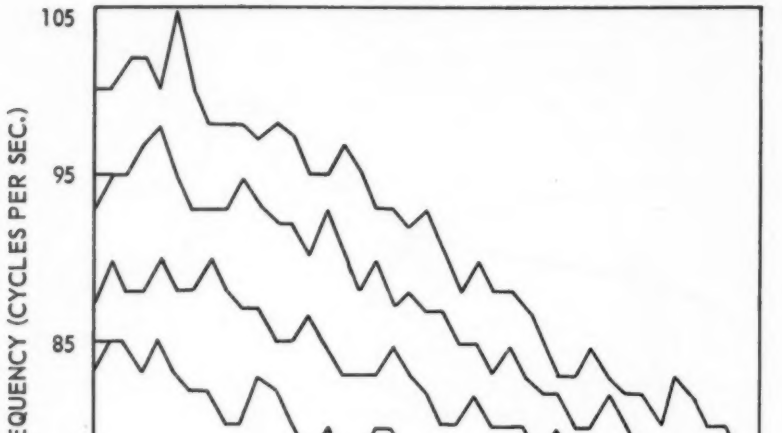


Fig. 8. The variation in the wing-beat frequency and the effect of fatigue on the Douglas-fir beetle for four representative individuals.

Drosophila repleta, Chadwick (1939a) found that the frequency after complete fatigue was 50 to 60 per cent of the starting rate, while Magnan (1934) noted a reduction of one-third during experiments with a sphingid, *Macroglossa stellatarum*.

The wing-beat amplitude was reduced in some individuals but not in others. These changes which did occur failed to follow a definite pattern; in some cases recovery from previous reduction occurred. Changes in amplitude occurred at both top and bottom of the stroke, which is contrary to findings in some Diptera (Hollick, 1940), but is in agreement with observations made on another beetle (Atkins, 1958).

In a few cases, after flying on a mill for several hours, the beetle diminished or suspended the action of the outer wing, maintaining flight at a greatly reduced velocity. Hocking (1953) reported that *Simulium* and *Apis mellifera* also reduced the outer wing amplitude on flight mills. He suggested that this was an attempt by the insect to steer out of the circular path enforced by the mill.

The reduction in the wing-beat frequency that could be attributed to fatigue was considerably lower than that reported by other workers. However, the reduction might be somewhat larger if the readings were carried on to the point of complete exhaustion as they were with *D. repleta*. This point, however, would follow more than eight hours of flight in the Douglas-fir beetle.

Conclusions

Of the flight movements, the wing-beat frequency is most affected by environmental factors. These effects are passed on to the flight velocity, although the relationship does not follow a definite pattern. Temperature probably has a combined effect — direct action on the biochemistry of the flight muscles and indirect action through sensory mechanisms.

Relative humidity influences the various phases of flight activity possibly through its effect on the body temperature. The reduction in wing-beat frequency demonstrated at high relative humidities is probably due to the onset of thermal paralysis, which may be supported by the earlier occurrence of rate reduction in the test conducted at 85° F.

The effect of light is probably due to sensory stimulation rather than an action on the physiology of the flight muscles. The effect of light intensity may be reduced following adaptation and sensory equalization as it is during the turning reaction.

Fatigue has a direct effect on the flight mechanism and would probably have a more pronounced effect than shown in this paper if the observations were carried out to a point of flight cessation.

The relationship between the wing-beat frequency, wing-stroke amplitude and the flight velocity is not fully understood, due to widespread variation between individuals, but it seems likely that they are all closely integrated and that the influence of the above-mentioned environmental factors on wing-beat frequency and amplitude would be passed on to the flight velocity. In this case, the speed with which the beetles could reach new areas for infestation and the distance they might spread in a unit of time would vary widely from season to season.

Acknowledgments

I wish to thank Dr. M. A. Khan of the Entomology Division, Lethbridge, and Dr. C. V. Morgan of the Entomology Division, Summerland, for identification of the nematodes and mites respectively. Thanks are also extended to Dr. W. G. Wellington and Mr. R. R. Lejeune of the Forest Laboratory, Victoria, for reading the manuscript.

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(Received April 11, 1960)

First Record of the Family Camillidae in the New World (Diptera)

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The discovery of *Camilla glabra* (Fallen) in Ottawa, Canada, is the first record of the existence in the New World of any member of the interesting little family Camillidae. A single male specimen taken June 15, 1954, by D. G. F. Cobb while collecting insects in her garden, would seem to indicate the species is established here.

The family Camillidae consists of the single genus *Camilla* Haliday, which for many years was assigned to the family *Drosophilidae*. Frey, (1921) considered it sufficiently differentiated from the Drosophilidae to warrant separate status and erected the family *Camillidae* to receive it. Duda (1934), Wheeler (1952, p. 164), and Collin (1956) all recognized the group as a family distinct from the Drosophilidae. More recently, Hennig (1958, p. 665) placed it as a separate family in the Drosophiloidea, pointing out that while it has certain characters in common with Curtonotidae and Drosophilidae, it shows even more affinities with Diastatidae and Ephydridae.

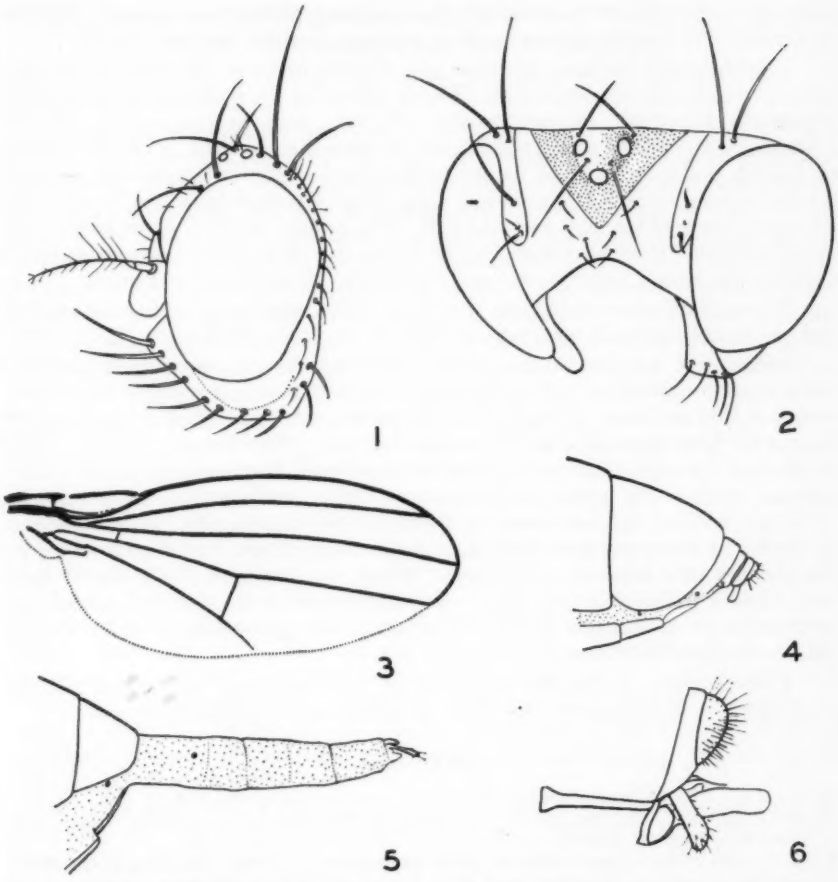

Fig. 1. Head, left lateral aspect, drawn from Ottawa specimen. Fig. 2. Head, antero-dorsal aspect, redrawn from Hennig, 1958. Fig. 3. Right wing, after Hennig, 1958. Fig. 4. Male abdomen, left lateral aspect, redrawn from Hennig, 1958. Fig. 5. Female abdomen, lateral aspect, after Hennig, 1958. Fig. 6. Male genitalia, lateral aspect, after Collin, 1933.

Adult *Camilla* spp. resemble *Drosophila melanogaster* Meig. in size and shape but the body colour is rather shiny black, sometimes with a metallic greenish lustre. There are eight species known in the genus, six from Europe and two from Africa. They all differ from Drosophilidae in possessing a bristly mesopleuron and in lacking sternopleural bristles. In addition, the anal cell (Fig. 3) is rudimentary (complete in Drosophilidae) and the anal vein (Fig. 3) is undeveloped (present in Drosophilidae). In these last two characters they resemble the Ephydridae but they differ from this family in possessing a pair of convergent postvertical bristles (Fig. 2) as in the Drosophilidae, (these are replaced by divergent ocellar bristles in *Ephydridae*) and in having the abdominal spiracles situated in the membrane (Figs. 4 and 5) (enclosed in the lateral margins of the terga in *Ephydridae*). *Camilla* spp. have a much less bulging face (Fig. 1) than

most *Ephydridae* and this character, plus the more distinctive vibrissae (Fig. 2) of *Camilla*, will usually serve as a quick means to separate the two families.

Camilla glabra (Fallen), as defined by Collin (1956) on the basis of Fallen's material, can be distinguished from all other species of the genus by the following characters: Frons and antennae partly yellowish, setae on oral margins behind vibrissae stronger than usual (Fig. 1); mesonotum shining black, without a patch of greyish pollen in front of the scutellum; dusting of third abdominal tergum limited to very narrow front margin; wing (Fig. 3) rather large and broad with a broadly rounded tip; legs and tarsi pale, anteroventral spine of front femur not very strong and situated relatively close to the end of the femur, almost directly opposite the strong, front posteroventral bristle. Genitalia as in Fig. 6.

I have compared the Ottawa specimen with a number of European species and am confident that it is a representative of *C. glabra* (Fallen).

Whether or not C. *glabra* is endemic in North America is an open question, but if so, it is difficult to understand why it has not been taken previously. It is quite possible, and even probable, that this species, otherwise known from Europe only, may have been accidentally introduced here. The Ottawa collection was made near the arboretum and gardens of the Central Experimental Farm which contains many trees, shrubs, and ornamental plants brought there from Europe. Although nothing definite is known about the life history of *C. glabra* it seems possible that living puparia might have been unknowingly introduced on, or in the soil and duff around, these plants. There is a possibility, too, that it may have been introduced in the same way with some of the many thousands of tulip bulbs given annually to the city through the generosity of H.M. Queen Juliana of The Netherlands.

Camilla glabra is not known to be of any economic importance but its occurrence in the Nearctic Region is of considerable academic interest.

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(Received August 25, 1960)

Observations on the Migration of Larvae of *Neodiprion swainei* Midd. (Hymenoptera: Tenthredinidae)[1]

By W. A. SMIRNOFF[2]

In the course of studies on *Neodiprion swainei* Midd. carried out in 1958 and 1959 in the region of Lake St. John, Que., mass migrations of *Neodiprion swainei* Midd. were observed. This paper gives a brief description of this phenomenon, which has never been reported heretofore, and discusses some of its implications.

On hatching from the eggs which are laid on the needles of the current growth of jack pine, *Pinus banksiana* Lamb., *N. swainei* larvae crawl to the old foliage where they feed in colonies of 40 to 70 individuals. At times, when larval populations become so great that all the foliage is destroyed, mass migration begins. The larvae gather in large clusters at the top of the tree where they remain for two or three days. At this time some of the larvae moult. The larvae then abandon the tree by crawling down the trunk or by dropping to the ground. They then creep on the ground, up and down stumps, in search of jack-pine trees with foliage. The migrating larvae are pale yellow in colour, probably as a result of their starved condition, and large numbers perish before they can become established on proper food. Those that manage to reach new food supplies quickly recover their original dark-green pigmentation.

The migrating larvae sometimes gather in large numbers on such objects as tree stumps where they rest for two or three days before resuming their search for food. Larvae were able to infest jack-pine trees situated 200 yards or more from their original feeding site. Newly occupied pine trees are readily recognizable; the needles of the current year's growth show few, if any, *N. swainei* egg-scars, and defoliation of such trees first takes place at the lower crown-level; when this foliage is consumed the larvae move to higher foliage. Colonies on newly occupied trees are usually two or three times larger than the original colonies and consist of 120 to 170 individuals, but as feeding progresses, the larvae may separate into smaller colonies.

In 1958 and 1959, in the vicinity of St. David de Falardeau in the Lake St. John area, many pine stands that were only lightly infested in the early summer were completely stripped of foliage by August. Most of this defoliation took place within a period of two weeks and was the result of invasion by migrating larvae.

In the course of studies on the action of a virus disease on *N. swainei* it became apparent that diseased larvae were subject to mass migrations. This occurred most commonly at the time of the third to the fifth larval instars when the incubation period of the disease usually takes longer than it does for earlier instars. Infected larvae lose their gregarious habit and wander at first in an apparently undirected fashion. They then gather on branches receiving the most light (this is not to be confused with the phenomenon of heliotropism normally exhibited by healthy larvae), and three or four days later begin to crawl in specific directions, settling on trees partly stripped of their needles; they then fall to the ground and either die of the disease or start spinning cocoons prematurely.

Infected fourth- and fifth-instar larvae may survive as long as 20 days before dying of the disease. The analysis of the mid-gut epithelium of such migrating larvae has shown that the disease is usually localized in the nuclei of a few cells and develops very slowly. The disease is not necessarily fatal to the insect and some of the infected larvae that spin cocoons may reach the adult stage the

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following summer. The females of such adults, however, are capable of transmitting the disease to their progeny. The phenomenon of mass migrations in search of food exhibited by the starving larvae of *N. swainei* at times of high populations results in a higher survival of the insect but on the other hand, the mass wandering of larvae infected with the virus disease results in a wider dissemination of the disease and increases its efficacy as a natural control factor.

Acknowledgment

Thanks are expressed to Dr. J. R. Blais of the Forest Biology Laboratory, Quebec, who kindly assisted in the preparation of the manuscript.

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Laboratory Evaluation of Resistance in Rutabaga Varieties to the Cabbage Maggot, *Hylemya brassicae* (Bouché) (Diptera: Anthomyiidae)[1]

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Previous studies have shown that some varieties of rutabagas in the field have resistance to the cabbage maggot, *Hylemya brassicae* (Bouché) (Swailes, 1959). It was evident that at least two factors were involved in resistance: (1) larvae encountered difficulties in initiating feeding and (2) larvae encountered resistance to growth. The latter factor was considered in the present study.

Methods and Materials

Eggs of the cabbage maggot were collected in the field during the adult flights in August and September of 1958 and 1959. The eggs were hatched on moist blotting paper in petri plates and held at approximately 20°C. Roots of the varieties of rutabaga to be tested (Tables I and II) were harvested immediately before use. They were at the stage of growth in which the greatest damage occurs in the field. Cores, ⅛ inch in diameter, were taken from the roots. Each core was cut to ¾ inch in length and the cortex tissues were removed. A small slit was made in one end of the core and a newly hatched maggot was placed into this. The core was placed slit-side down on a piece of moist blotting paper in a 4-dram shell vial that was then closed with a cork. The vials were stored at 15°C. and the food pieces were examined periodically for rot. In 1958, much food had to be replaced because of soft rot, but this was avoided in 1959, as more care was taken in surface sterilization of the apparatus and transfer area.

In 1958, 12 rutabaga varieties were tested with 85 larvae on each variety. In 1959, 100 larvae were started on each of six varieties.

In 1959, another 70 larvae were put on pieces of cortex of each of the six varieties. Cortex sections were cut from the root surface with a cork borer to a size that fitted tightly into the vials. Four sections were packed at the bottom of each vial. The top section, containing a maggot in a slit on the underside, was placed with the outer surface of the root uppermost.

Results and Discussion

Tables I and II show the results of feeding on root pieces in 1958 and 1959.

No significant differences were found in either year among the numbers of insects that pupated in each variety when the results were analysed by the chi-square test.

[1]Contribution from the Entomology Section.

TABLE I

Effects on larvae of *Hylemya brassicae* of feeding on root pieces of 12 rutabaga varieties in 1958

Variety	Percentage pupated	Percentage dead in 3rd instar	Percentage not established on food	Weight of puparia (mgm.)		Hatch to pupation (days)	
				Mean	s.d.	Mean	s.d.
Alta Sweet	81	6	13	18.0	± 2.6	41.1	± 6.7
Golden Neckless	80	11	9	16.9	± 2.7	39.9	± 7.9
Lord Derby	78	5	18	16.5	± 2.4	40.8	± 6.9
Victory Neckless	75	16	8	17.1	± 2.7	40.6	± 6.0
Laurentian	75	15	9	17.0	± 2.7	41.5	± 7.8
Ditmars Bronze Top	75	12	13	16.9	± 2.6	38.8	± 6.7
Westbury	75	12	13	16.6	± 2.9	37.2	± 7.7
Johnsons Favorite	75	16	8	16.1	± 2.4	36.9	± 5.8
Golden Table	71	18	12	16.6	± 2.4	37.4	± 5.5
Yellow Bronze Top	69	12	19	16.8	± 2.7	38.2	± 6.8
Wilhelmsburger	66	22	12	16.8	± 2.8	37.5	± 5.7
Canadian Gem	60	12	28	16.5	± 2.4	38.4	± 6.5

Comparisons show that survival to the pupal stage was higher in 1959 than in 1958, and that the variation between varieties was smaller. Of the varieties tested, Wilhelmsburger permitted the highest survival in 1959 whereas the same variety permitted next to lowest survival in 1958. The contrast in survival between the 60 and 90 per cent found in these tests and the 4 to 25 per cent found in field samples (Swailes, 1959) is probably the result of egg mortality, which has been described in detail by Hughes (1959).

Larvae became established on cortex pieces but few pupated perhaps because almost every rutabaga showed some soft rot. The pieces had been fitted tightly into the vials to help prevent dessication and the food could not be replaced without damage to many of the maggots. The percentage of the larvae that started feeding on each variety was:—

Ditmars Bronze Top	73
Alta Sweet	70
Laurentian	68
Westbury	67
Canadian Gem	67
Wilhelmsburger	63

Fewer larvae established themselves on cortex pieces than on cores and this suggests that the cortex is less satisfactory for initiation of feeding, although it is normally the tissue on which the maggot first feeds. There was little difference among the percentages of larvae that established themselves on cortex pieces of

TABLE II

Effects on larvae of *Hylemya brassicae* of feeding on root pieces of six rutabaga varieties in 1959

Variety	Percentage pupated	Percentage dead in 2nd & 3rd instars	Percentage not established on food	Weight of puparia (mgm.)		Hatch to pupation (days)	
				Mean	s.d.	Mean	s.d.
Wilhelmsburger	92	6	2	16.0	± 2.4	34.9	± 8.8
Westbury	86	8	6	16.7	± 2.9	35.7	± 9.6
Alta Sweet	86	8	6	16.0	± 3.0	35.4	± 10.7
Ditmars Bronze Top	85	10	5	16.2	± 2.4	37.5	± 9.7
Laurentian	82	12	6	15.8	± 2.8	35.4	± 9.5
Canadian Gem	77	13	10	16.1	± 2.9	34.5	± 10.4

different varieties; Wilhelmsburger, on which percentage establishment was lowest, also had the lowest survival from egg to puparium in field tests in 1956 and 1958 (Swailes, 1959). However, establishment of larvae on root cores without cortex was highest on Wilhelmsburger in 1959 and fifth highest in 1958 or second highest, if only the varieties used in 1959 were considered (Tables I and II). Consequently, resistance in Wilhelmsburger is principally a characteristic of the cortex tissues.

In contrast, Canadian Gem permitted the smallest number of larvae to pupate in both years in the laboratory. This was the result of poor establishment and of fairly high mortality of second- and third-instar larvae. A type of resistance different from that found in Wilhelmsburger is involved.

The similarity of weights of puparia and the time required to develop through the larval stages on all rutabaga varieties tested suggests that the nutritional value of the varieties is equal. This further supports the evidence found in the field (Swailes, 1959) that resistance is most likely a characteristic of the cortex tissues in Wilhelmsburger along with some other type of resistance in Canadian Gem.

Summary

A method is described for rearing individual *Hylemya brassicae* larvae on root cores of rutabaga in vials. In 1959, 77 to 92 per cent pupation was obtained.

The similarity of pupal weights and duration of larval periods suggests that once established the larvae are sustained equally well on all varieties.

In the variety Wilhelmsburger only three or four per cent survived from egg to puparium in previous tests. Survival rates of 66 and 92 per cent on root cores and establishment of 63 per cent on cortex tissues were obtained in the laboratory. This indicated that the resistance found in the field was to initiation of feeding.

Survival of larvae on the variety Canadian Gem was low in all tests because of the failure of the maggots to establish on the root cores and because of relatively high mortality in the second and third instars.

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